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ABSTRACT

This publication contains a review of trends in research over the past decade followed by 24 studies focusing on cognitive structure, instructional strategies, curricular issues, and attitudes. Among the specific areas investigated are: concept maps as reflectors of conceptual understanding; equations, translations, and number skills in learning chemical stoichiometry; responses to diagnostic, multiple-choice, physics items; children's explanations of natural phenomena; reading and the science learner; students' understanding of space, velocity, and acceleration; student beliefs about place value and decimals; beginning student teachers' opinions about teaching primary science; teacher behaviors and student task involvement within small group and individual activity settings; cognitive preferences and chemistry achievement; investigatory learning in elementary school science; hands-on science program for the intellectually immature high school student; implications of research on alternative frameworks for science teacher education; dimensions of cognitive demand; attainment of an attitudinal objective (belief in the value of community and personal health); arrows in science diagrams; origin and development of the modern science textbook; and use of a repertory grid technique to analyze students' reactions to science. Each study includes rationale, methodology, results, and conclusions. (JN)

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**RESEARCH
IN
SCIENCE EDUCATION**

Volume 13

Selections of papers from the Fourteenth Annual Conference of the Australian
Science Education Research Association, University of Waikato, New Zealand

May 1983

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PREFACE

The majority of the papers presented at the annual conference of the Australian Science Education Research Association in May 1983 at University of Waikato, New Zealand, are contained in this volume of Research in Science Education. The issue begins with White's review of trends in the research over the past decade. He indicates that research has become more complex and more relevant in the last years as it has become based on more detailed models of relations between constructs. He also predicts an advance in the theory of learning in science within the next few years.

Quite a number of the subsequent papers deal with matters associated with explorations of cognitive structure. Brumby, for example, raises the question of whether concept mapping can be refined to demonstrate the processing of concepts and their linking relationships. She describes a written task in which pupils showed different patterns of working through a prepared concept map. Edwards and Fraser studied the concept mapping technique for its potential to provide an indicator of the level of understanding pupils bring to a learning situation, while Fawns compared concept maps for ASEP units drawn by experienced and student-teachers and used to make overt their views of the science syllabus. Dall'Alba and Edwards identify the dimensions of a cognitive task which determine how demanding it is and pupils' concepts of velocity and acceleration and rock are probed by Jones and Happs, respectively. Schollum adds another perspective to the research by showing that pupils often give meanings to arrows in scientific diagrams that are not intended, and Carr indicates that many 12 to 13 year-olds have incorrect ideas about numbers with decimal fractions with consequential effects in those science topics that require decimal fractions. Hope and Townsend and Northfield and Gunstone discuss some of the implications that research on student teachers' understanding of science concepts and children's frameworks for interpreting natural phenomena have for pre-service teacher education.

Teaching-strategy and curricular issues are addressed by Blake who proposes a 'hands on', science based, compensatory education program for intellectually immature early-leaving secondary school students and by Biddulph, Osborne, and Fryberg who describe the Learning in Science Project (Primary) at the University of Waikato. But compared to a decade ago there are fewer reports about teaching and interaction in science classrooms although in this issue Harlen uses her experience with the APU work in science to present some ideas about the relationships between process skills and concepts and Beasley studies the relationships between teacher

u l m

behaviour and pupil involvement in learning tasks. His findings suggest that teachers who wish to encourage small-group learning activities must nevertheless maintain their 'contact' with the whole class.

Several papers deal with issues associated with attitudes (Appleton; Jones & Butts; Maddock), others (Fensham; Gauld & Ryan) with learning difficulties and diagnosing misunderstandings; one with cognitive preferences and achievement in chemistry (McRobbie), one (Symington & White) with children's explanations of natural phenomena, and another (Bell) with processes used to learn from text. The remaining two papers in this issue introduce new techniques and themes into the research. Stead reports on the use of the repertory grid technique to analyse pupils' reactions to science and Lynch and Strube report on Strube's refreshing historical analysis of science texts. Once again this volume of Research in Science Education reveals the diversity of interests and of issues reported at the annual conference.

Richard P. Tisher
Editor

RESEARCH IN SCIENCE EDUCATION: THE PAST TEN YEARS AND THE NEXT FIVE

Richard T. White

INTRODUCTION

Recently Richard Tisher and I completed a review of the past 10 years of research in science education, to be published in the Third Handbook of Research on Teaching. The general principles we derived from the vast body of literature we had to read may enable us to look a little into the future, setting out directions in which research might progress. The difference between research 10 years ago and now is so great that I am not prepared to hazard prophecies for more than the next five years, and even at that I would not be surprised to find that research, as it often does, has gone in a direction which only appears inevitable in hindsight.

In the Sciences chapter of the Second Handbook, Shulman and Tamir (1973) took as their chief themes the structure of knowledge and the impact of the great centrally-produced curricula. By the time we had come to write our chapter, these had been transmuted to the learner's acquisition of knowledge and the processes of curriculum development, dissemination, adoption, and implementation. The shift in themes reflects a growth, over the 10 years, in concern for details, for mechanisms of effects. Researchers became anxious to know not just that one variable is related to another, but wanted to know how, why, the relation operated.

Concern for mechanisms required researchers to attend to and develop subtle, complex theories. Piaget became popular in the past decade. It may come as a shock to realise that Shulman and Tamir (1973) make only four passing mentions of Piaget, and cite only one reference, by Tisher (1962) incidentally, that is based on Piaget's theory. As well as Piaget, theories from cognitive psychology - Ausubel and information processing notions - were the source of many studies. We should recall that it is only 15 years ago that Ausubel published his book Educational Psychology, and more or less defiantly added to the title, A Cognitive View. At that time behaviourism was dominant. More recently we have other constructivist theories being taken up by researchers. Examples are Wittrock's generative model of learning (1974) and Kelly's personal construct theory (1955).

These subtle theories introduced an extensive range of concepts to research. Notions of cognitive structure, learning strategies, wait-time, curriculum implementation, cognitive styles, were rare or absent in research in the 1960s.

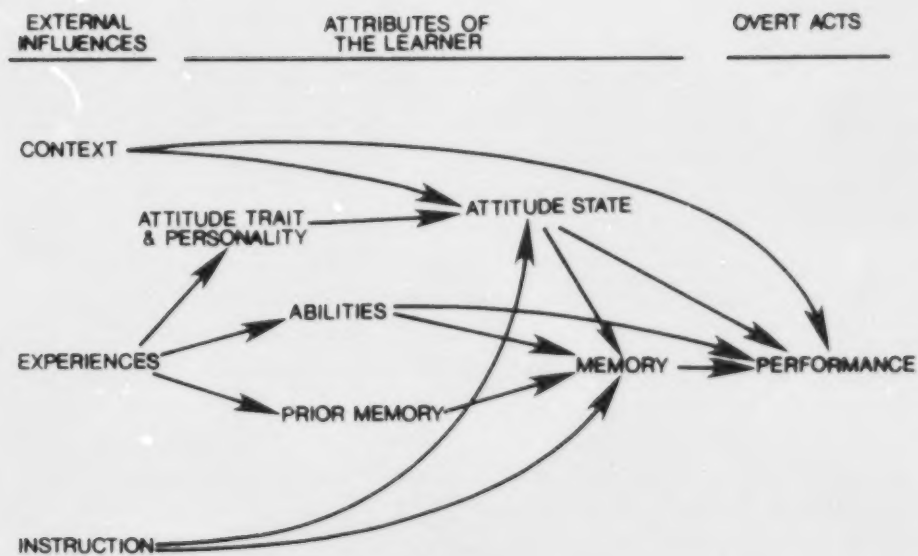
The detailed theories and numerous concepts led researchers to operate with more complex models of causal relations between classes of variables than they had previously. The model behind most studies of teaching and learning 10 years ago seems to have been the very simple one that Instruction determines Performance. A couple of years ago I described how the research I had been associated with had progressed, and how the model underlying that research had changed (White, 1981). Now that I have read nearly everybody else's research, I can see that similar development occurred in lots of fields. It would be wrong to believe that there is one new complex model that is the correct and most useful representation of relations among variables. Research has become so diverse and involved that each of us will have a preferred version. My point is that the model you now use is almost bound to be more complex than the one that was current in your field 10 years ago.

In writing our chapter, Tisher and I found it convenient to divide it into sections which came from a particular model of the relation between teaching and learning. The model is in the Figure below. As you can see it is much more complex than the simple two-element one of Instruction - Performance.

The main distinction between the complex model and the simple is that the complex puts the learner in the picture, and so allows for consideration of individual differences. The centre block of the Figure refers to characteristics of the learner. Much of the research of the late 1970s and early 1980s concentrated on those characteristics. Earlier research did not, and indeed could not, because the characteristics were not part of the model on which the researchers operated.

It is inevitable that a concern for mechanisms and an interest in subtle theories and complex models would affect the questions researchers asked and the methods they employed. Once researchers began to ponder how past experience influenced new memory structures, they had to shift from the dominant style of the 1950s in which groups of learners were compared en masse with each other. Although large scale experiment still has its place, it has been supplemented by case studies. As well as group tests we now use interviews. Self-report data are no longer beyond the pale. Observations of the process of teaching and learning have been added to measures of outcomes.

These developments have gone further in some fields than others, of course, though none has been untouched. Tisher and I found it easy to produce examples in the work on cognitive structure and the probing of understanding, classroom questioning, and curriculum dissemination and implementation, and in the more recent studies of laboratory work. Research on attitudes has yet to benefit much from the concern for mechanisms. Research on abilities is a particularly interesting



field. In the Handbook chapter we dealt with abilities under only three heads: work on problem solving, cognitive preferences, and Piagetian studies. We did not go into other areas such as serialist-holist or surface-deep processing because we were short of space and because those areas are less specific to science education. Of the three sections, only the one on problem solving appears to concentrate on the learner as an individual, and that may be because it was taken up later than the other two. Cognitive preference work has its roots in the mid-1960s, and continues to involve pencil-and-paper tests being administered to large numbers of students. It has not developed to include clinical methods as well. It once promised to be an important field, but now the only people keeping it alive are those such as Tamir and Kempa who were involved with it a decade ago. Unless these researchers manage to shift the cognitive preference studies from measuring of relations between preferences and other variables to uncovering the mechanisms behind the relations, this field will wither away. It may be foolhardy to make the same prediction about Piagetian studies. It could happen though, because the bulk of Piagetian work has ossified into mass studies in which, ironically when one considers Piaget's concern for the individual, children are forced into labelled groups. Nearly all of the Piagetian work falls into four categories: development of group tests to replace Piaget's clinical interview technique; assessment of the proportions of a population in each of Piaget's stages; measurement of the relation between stage membership and another variable, such as school performance; and attempts to promote attainment of stages.

Work in the first category runs contrary to the whole spirit of Piaget's work. In any case, it has failed. Correlations between assessments made through interviews and those made through group tests are at best moderate, and often low, even negative on occasion. Results from the second category are so diverse that the only conclusion that should be drawn from them is that any group will contain such a range of development that no guidance can be provided to the teacher on what should be done except to treat the group as individuals. The third category studies tell us nothing of value. The correlations that are observed are not illuminating, and as a guide to selection or other action measured stage membership turns out to be less useful than measured intelligence or prior performance. Many of the studies in the fourth category can be castigated as attempts to coach people in test performance. Few have attempted to show that the training led to acquisition of an ability that enabled superior performance across a wide range of tasks. There are exceptions, but they are in danger of being lost among thousands of useless, repetitive articles.

The style of Piagetian research contrasts with that on memory structures and the probing of understanding. Although group measures are used in this work, a high proportion of studies employs interviews. Where the tendency in Piagetian work has

been to shift away from the inconvenient use of apparatus to print, and from open interviews to structured tests, the memory and understanding work has moved the other way. A connection can be traced, for instance, from the group measures of cognitive structure used by Shavelson (1972) a decade ago to the individual interviews and deep probing used by Happs (1980), Bell (1981), or Symington and myself (Symington & White, 1983). The contrast between what has happened in Piagetian research and cognitive structure research delineates both the promise and the threat of the future. We could go on, probing ever deeper into processes of learning and teaching, or we could regress to a sterile multiplication of studies which, for convenience sake, would gradually come to be more and more measures of performance of groups. In my more pessimistic moments I fear that the latter is almost the inevitable consequence of a line of research becoming popular.

If the worst happens to cognitive structure research, some of us might want to move on. There are some relations in the Figure which await attention. Perhaps the chief of these is the influence of context. Although most reports of research give some information about the conditions under which the study was done, we really know very little about the effect context has on learning. Among other consequences, this means that research has little to say about the organization of schools. Research would be of more immediate value if we knew more about how outcomes were affected by aspects of context such as form of school organization, degree of separation of learning situation from everyday world, general classroom climate, assumptions of the society about the purpose of schooling, and so on.

Another example of a potentially rich field is the influence that personality or attitude trait has on attitude state, and that in turn on memory structure and performance. Shulman and Tamir (1973) urged that more research be done on attitudes, and indeed there is a lot. Nearly all of it, however, concerns attitudes as outcomes, as dependent variables affected by different forms of instruction. Very little has been done on the role of attitude as the determinant of learning.

As well as the shifts in methods which we have seen, the past decade of science education research has two other characteristics which should be appreciated. One is the growth in amount of research. It appeared to Tisher and me that we had to review several times as much research as Shulman and Tamir were faced with, and, incidentally, had to compress it into about three-quarters as many words. The Shulman and Tamir review is much more extensive than its predecessor, that of Watson (1963) in the first Handbook. To re-read Watson's review now is to step back into a small, simple world. One author alone, Kruglak, accounts for one-sixth of the studies Watson cites. If we extrapolate forwards, our successors doing the review for the Fourth Handbook will face a truly formidable task; a more serious consequence

would be that the science education field would fragment, as the larger field of education has already. The growth may not continue, of course, but we should be planning now how to cope with it if it does happen.

The other notable characteristic is the growth of science education research outside the United States. When Shulman and Tamir were writing their chapter nearly all science education research was American. The Australian Science Education Research Association was just being formed. I know of no Australian doctoral theses in science education that are earlier than 1968. Things were no better, indeed possibly worse, in Europe. It is very different now. ASERA flourishes; many centres in Australia are active; the Science Education Research Unit at the University of Waikato has a high international reputation; Israeli schools of science education generate many publications; Leeds, Chelsea College, Göteborg, and Kiel are well-known; and Studies in Science Education and the European Journal of Science Education are established journals of quality.

With these developments in style, quantity, and dispersion of research in the past decades, what does the future hold? There are both negative and positive prospects.

Growth encourages negative changes. As I discussed in the comparison of Piagetian and cognitive structure research, good studies can be lost in a forest of bad. I do not much care to put forward an elitist argument, but it does seem probable that when a field becomes popular much of the work that follows the initial pioneering phase is pedestrian. It could happen, then, that unless the rate at which new ground is broken is maintained, or increased, science education research could become repetitive and trivial. Another problem with growth is perhaps already evident. When a field of research becomes big enough it becomes self-sufficient, and the practitioners within it feel no need to look outside it. Rat psychology is an example. We must guard against science education research becoming divorced from practice. There are plenty of anecdotal accounts of regression by teachers to texts, curricula, and methods that were popular in the 1950s. The gulf between research and practice may be widening rather than closing, and research is in danger of becoming an esoteric pursuit.

Another negative influence is the decline in the world economy. The lack of funds for individual projects is not the problem, since good research can be done for almost nothing provided there is a good researcher to do it. That is the heart of the problem. As funds dry up, the stream of new researchers is choked. Old researchers are useful, but they tend to stick with old ideas.

On the positive side, there seems to be a lot of steam left in the research into understanding. I am excited by the prospects opened up in John Baird's work on cognitive strategies (Baird & White, 1982), and by the direction of the Learning in Science Project (Primary) in its study of how young children construct their view of the world. There are plenty of other active fields with which I am less familiar. Also there are potentially rich fields such as the notion of context which I described earlier.

In an address last year (White, 1982) I argued that theories, models, questions, and methods interact, and that advances in one promote advances in the others while no one element can drag too far behind without arresting the others. In the last decade, advances in theory made possible the dramatic progress we have seen in the other three. Now it appears that theory is falling behind. Therefore I anticipate an advance in the theory of learning in science within the next few years. The form of this advance is not certain, though I expect it to be a synthesis of the constructivist theories of Wittrock, Kelly, Marton, and Piaget (without stages), information processing, cognitive psychology, and personality theory. Such a synthesis would spur research again, and the more dreary prospects I have alluded to would be avoided.

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CONCEPT MAPPING: STRUCTURE OR PROCESS?

Margaret Brumby

INTRODUCTION

Over the last few years concept mapping has emerged internationally as a method for studying students' knowledge and understanding of science. Much of this development has been reported at ASERA conferences.

One of the earliest studies of the way students related concepts was by word association lists, such as Schaefer's (1979) studies on the concept of growth. Novak (1976) was one of the first to call his schematic representations a concept map. Initially the focus was on the concepts used, and little attention was given to describing the links. The importance of these links was appreciated by Novak (1980) in his concept map of the ear. Fensham, Garrard and West (1981, 1982) also focussed on the relationships between concepts, even providing participating students with a list of possible linking relationships to be used in developing their own maps about the structure of matter. Several of these (e.g., 'is a member of') strongly suggested a hierarchical classification instead of a broader concept map. Champagne *et al.*'s (1981) descriptions of basic geological concept maps also had a strong hierarchical flavour.

Attempts have been made to quantify the size of the links. Gunstone (1980) used path analysis methods in studying the relationships between force and mass. Schaefer (1980) developed arbitrary axes for his categories of word associations and definitions of two concepts, health and environment. This latter method resulted in spatially defined map areas. However the actual value of the units of measurements was not clear. The importance of the nature of the links was clearly drawn out in recent reviews of techniques used for concept mapping as a tool in research (Sutton 1980; Posner and Gertzog 1982; White 1983).

Recent work, taking much broader areas of knowledge (e.g., genetics) has resulted in enormous, idiosyncratic maps (Baird and White 1981), which are difficult to interpret and impossible to compare. It is therefore timely to stop and consider whether concept mapping is taking us anywhere, or whether it is an interesting, but

limited, tool in research. What are our aims in using concept maps? Their limitations are obvious - they do not capture the students' thoughts as they develop their own maps, they do not show the order in which the students worked up their maps, and at the end there is a static, fixed structural representation of the particular area under study. Most researchers agree however, that human knowledge is dynamic, and relationships between concepts are not fixed in space or time but are continually redefined relative to a given topic. Can concept mapping be considered, not as a structural representation, but as a processing of knowledge? If the latter is possible, then can methods be developed to observe such processing more accurately?

A recent study, which involved a given biological concept map, provided considerable information about qualitative differences in the way students integrated unfamiliar knowledge with their own existing knowledge. In this method, students were required to describe a concept map of Immunity in their own (written) words (Brumby 1982). An extension of this method, using a carefully prepared concept map which was then described by a group of 32 first-year tertiary medical students, forms the basis of this paper.

METHODS

1. The task

A concept map based on 'in vitro fertilization and embryo transfer' was prepared for overhead projection (Figure 1). Linking lines were drawn between the concepts, which were problems associated with this new technique. The only links which were labelled in any way were those where timing was crucial. A circle (unlabelled) enclosed that part of the map representing the actual laboratory fertilization process.

This overhead (Figure 1) was shown to a group of first-year medical students (n=32) during a regular class. At the time, the topic was receiving considerable media publicity. The topic was briefly introduced as 'test-tube babies', then with a definition of IVF and ET. The following instructions were given just before the overhead was shown:

I'm going to show you a diagram summarizing the key steps and problems associated with In Vitro Fertilization and Embryo Transfer (IVF and ET). I want you to study the diagram for a couple of minutes, in order to sort it out in your own minds, and then, when I say, I'd like you to explain IVF and ET, as clearly as you can, in your own words.

The diagram will remain on view all the time, this is NOT a memory test. I will not answer any questions after it is on, because I don't want to focus your thoughts in any way'.

Students were allowed up to 30 minutes to write out their description.

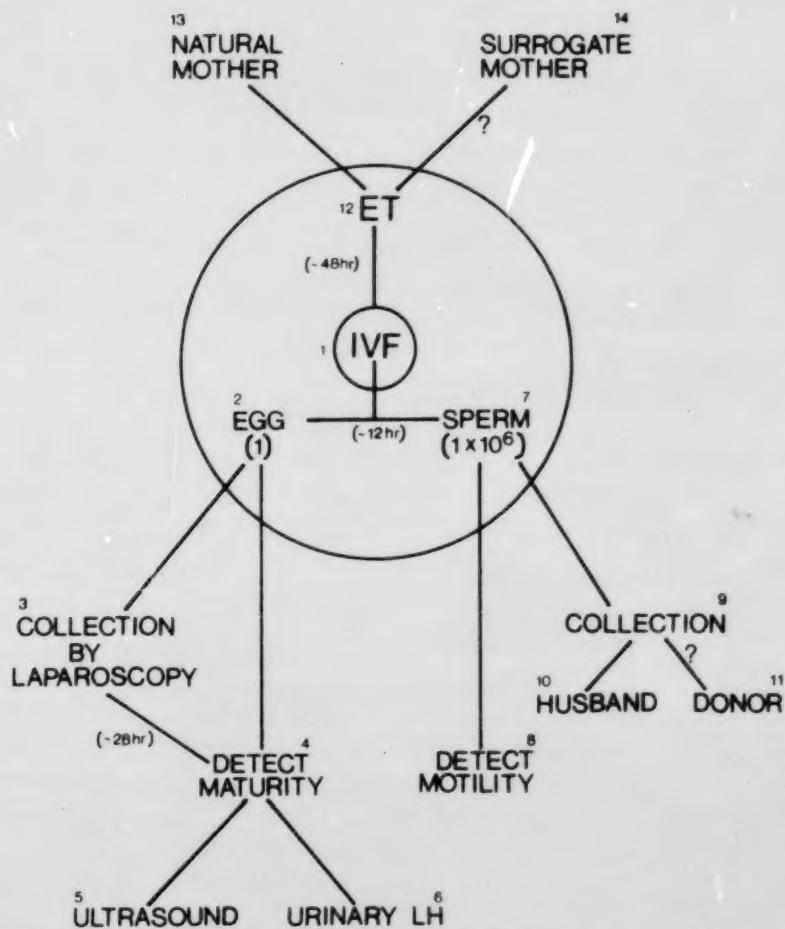


FIGURE 1
IN VITRO FERTILIZATION and EMBRYO TRANSFER

2. Analysis of descriptions

Each point on the concept map was given a number. Further symbols used in analysis of student descriptions were:

- ↔ comparative statement between two points not linked on the map
- + additional information not on map
- t reference to time as shown at several points on the map
- x error - a biologically inaccurate statement

Using these coded symbols students' descriptions were analysed phrase-by-phrase. This resulted in a symbolic and numerical translation of the students' descriptions. The numerical sequence revealed the direction in which a student worked through the map, and further, showed any gaps where a student omitted any portion of the map.

RESULTS

1 Order of processing. Distinctive patterns of processing the concept map were found. The following two examples illustrate the variation. Analysis is shown below each example.

(a) Approximately half the students broke the map into three spokes of a wheel, then further subdivided these spokes step-by-step, preserving the internal order of the concepts. These descriptions resembled a flow sheet of the IVF technique.

E.g., (a)

- 1 Using various methods such as ultrasound the maturity of eggs in the natural mother's ovary is detected. After a mature egg is detected it is removed from the ovary 28 hours later by the method of laparoscopy.
- 2 Simultaneously mobile sperm (1×10^6) are collected from the testicle either of the woman's husband or donor.
- 3 Both sperm and egg are then contained separately for approximately 12 hours.
- 4 After this 12 hours have elapsed the sperm and egg are introduced into a single glass container where fertilization takes place and thus a zygote forms.
- 5 48 hours after the combining of the sperm and egg the embryo is then transplanted into the uterus of either the natural or surrogate mother. From then on development of the embryo continues as any other'.

Analysis gave the following codes:

5 4 2 13 + 4 2 1 3 / 8 7 7' 9 + 10 11 / 7 2 1 / 1 7 2 1 / 17 2 12 + 13 14 +

(b) Several students disrupted the linked order of the map by drawing together comparative concepts.

E.g., (b)

'In vitro fertilization' occurs when the female zygote or egg is placed into contact with the male zygote or sperm cell. Both must be collected after they have shown signs of maturity, in the case of the egg, and of motility in the case of the sperm cell. Depending on the circumstances behind the natural parents' inability to produce normal gametes, a donor may be used to compromise the lack of sperm or ovum. This process of fertilization takes place in a vitro environment, similar conditions to that of the uterus. A large number of sperm are used in an attempt to fertilize one ovum.

Once fertilization of the two gametes has occurred, which must occur within 12 hours of the bringing together of the two gametes, the zygote remains in the given environment for approximately 48 hours. From here the embryo is transported to the uterus of the surrogate mother, if she is able to provide suitable pregnancy conditions otherwise the natural mother (who donated the ovum?) is the provider of the site of pregnancy, and here pregnancy gestation period follows (9 months)

Analysis gave the following codes:

1x2 ↔ 7,3 ↔ 9,4 ↔ 8, ++ 14 ↔ 11(?) ++ 2' ↔ 7' / 1 1 + 1 12 + 14 ↔ 13 + + +.

Nearly one third of the students' descriptions showed both step-by-step and comparative statements.

2 Integration with existing knowledge. The instructions 'to describe [the map] as clearly as you can, in your own words' do not explicitly state that additional information should be used. One of the purposes of this task was to observe how spontaneously (i.e. uncued) students did use their existing knowledge and relate it to new concepts. Wherever additional knowledge was used, a code symbol '+' was recorded. The total number of +'s therefore indicated the degree of integration with existing knowledge.

For this task approximately two-thirds of students used no additional information at all, or only the two words 'pregnancy' and 'zygote'.

The remaining one-third used from 3-11 additional concepts, richly explaining IVF as they understood it. Example (a) above shows some integration, example (b) above shows considerable additional knowledge integrated into this description. These two examples demonstrate that integration with existing knowledge appears independent of the order of processing the concept map.

3 Gaps. The parts of the map most frequently omitted were ultrasound and urinary LH. Other 'extremities' of the map, i.e. laparoscopy and mobility were omitted by several students.

4 Errors. Two main kinds of errors were found. The most common error involved confusion about the identity of the egg donor, whether it was the natural mother or a surrogate mother. This problem seemed to occur because these students started at the top of the map and worked hierarchically down.

This order often led to the second main error, i.e. confusion about the details of the egg, where it matures, when it is collected, and whether it is an embryo before it becomes an egg!). These errors are illustrated in the following example (c).

E.g. (c)

'The formation of the test-tube baby involves several separate processes. At least one million sperm from the husband (or a donor if the husband can't supply it) is collected. The unfertilized eggs from the mother (or a donor) are transplanted by embryo transplantation into the test-tube. The embryo transplant takes approximately 48 hours. The sperm is detected for motility before being allowed to come into contact with the female cells. The sperm are then brought into contact with the unfertilized cells for approximately 12 hours. The eggs are then collected by laparoscopy. Approximately 28 hours later the eggs are detected for maturity by ultrasound or urinary LH.

Analysis gave the following code:

+ 7' 10 11 + 9 / 2 13 ? 14 x! 12 / T 8 7 2 T / 2 3 T 4 5 6.

Other errors recorded were a mis-reading of mutility for motility (in which instance the student added: 'presumably the frequency of mutations'); embryo 'transfer' became 'transport' or 'transplant'.

DISCUSSION

This task essentially required students to make sense of the links. The richness of the descriptions and the industry with which they worked suggests that students did not find the task obscure or tedious. They also had to start at a point from which a coherent description could be made. In this task this was not at the top, as is usual in a hierarchy or in a flow chart.

Approximately half the students saw the map as three spokes radiating from a central point. In their descriptions students proceeded along each spoke step-by step, faithfully preserving the order of the map and rarely omitting any points. These descriptions often became flow-charts of the IVF process.

A small group of students disrupted this order by drawing out comparative ideas. Several were possible: the gametes, their relative numbers, problems of collection, detection of motility and maturity, questions of surrogacy or donor sperm, and also uncertainty in timing at various stages. Many more omissions were found in these 'disrupted' descriptions, which in general did not resemble flow-charts.

The other large group of descriptions included both sequences along some spokes and some comparative statements. These findings on this IVF task are extremely similar to an earlier study using a concept map of Immunity (Brumby 1982), and which suggests that concept mapping may eventually be included in the large body of research into student learning known as cognitive styles.

These patterns of processing were independent of whether the students used additional knowledge in their descriptions. This point was easily detected because the content concepts of the prepared map were clearly controlled. Such integration of new with existing knowledge cannot be detected when completely free-style maps are generated by students, and may be missed in card arrangement methods.

How useful then is concept-mapping in education and educational research? The findings reported here cast doubt on attempts to quantify or measure the size of the links between concepts. What could such quantification, using arbitrary units, tell us? There is yet to be shown convincing evidence that the shorter the link, the closer the relationship between the concepts. Furthermore, quantification into actual measured lengths may reinforce one of the major problems in concept mapping - i.e., that the map is a fixed, static shape.

It should not be surprising that no one method can adequately reveal a student's knowledge of and reasoning about a particular topic. Concept mapping alone may be useful, but a series of additional techniques may provide greater insight. Describing a prepared map may provide information on how a student processes a map. All methods which have been reported have been shown to have the potential to reveal misconceptions.

The greatest value of qualitative concept mapping however may be in its use as a teaching tool, for it explicitly shows students the importance of making links between new and existing knowledge. This may require students to actively re-sort ideas, and actively relate new ideas, in preparing a concept map of a particular topic being learnt. Both these active processes are significant steps towards overcoming the passive rote-learning of isolated 'bits' of knowledge, which seems such a feature of many students' school learning.

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CONCEPT MAPS AS REFLECTORS OF CONCEPTUAL UNDERSTANDING

John Edwards and Kym Fraser

INTRODUCTION

Over the past five years science education research in Australia and New Zealand has focussed attention on student misconceptions in science. Such researchers as Gunstone and White (1980) and Osborne and Gilbert (1979) have revealed some of the misconceptions that students acquire during their schooling. Revelations such as these have helped to emphasise the need for teachers to be aware of what conceptions and misconceptions their students bring into instructional settings.

In reviewing what educational psychology had revealed about the facilitation of pupil learning Lovell (1980) concluded:

First I believe that, in general, what the pupil knows today, what relevant anchorage he has, is the best single predictor of what he will know tomorrow as a result of your teaching ... Second, it is necessary for the teacher to try and establish the main ideas held by pupils at the time they begin to experience new material. Pupils hold many spontaneous strategies, misconceptions, and alternative frameworks ... Teaching must be adjusted to the anchorage the pupil already holds. At times interpretations of the pupil must be compared and contrasted with those of the teacher. Teachers can use individual interviews and concept mapping to establish ideas held.

Teachers roll their eyes in disbelief at the suggestion of a regular regime of individual interviews. The restructuring required to enable such a system to operate is massive and unlikely to be widely implemented in classrooms. Concept mapping, on the other hand, offers a technique for revealing cognitive structure which appears manageable within present classroom constraints. This paper reports on part of a pilot study which investigated the feasibility of using concept mapping in secondary science classrooms.

SETTING AND DESIGN

The study involved instruction in concept mapping for twenty-four grade nine science students in a small co-educational independent school in North Queensland. The students were drawn from two classes totalling sixty-three students. The sample students chosen were low and medium achievers as revealed by classroom tests. They

normally worked in pairs and these same pairs were used throughout the study. During each of three month-long work units, groups of four students were put through the following treatment:

Step 1: The four students were each given a list of approximately ten central concepts associated with the coming unit of work. They were asked to write down all they knew about these concepts, under exam conditions with no time limit.

Step 2: Individual audio-taped thirty minute interviews were held within one to three days of the examination. The focus of each interview was to reveal the students' understanding of these same concepts.

Step 3: A thirty-minute training program in concept mapping, done separately with each pair of students out of class time.

Step 4: Construction of concept maps during class and homework time over the four weeks of the unit. Individual on-going remediation was a part of this process.

Step 5: At the end of the unit each student constructed a concept map of the overall unit using a set of self-generated major concepts. This was done in their own time with no time limit.

Step 6: Individual audio-taped interviews were held within one to three days of this task. The focus of each interview was to reveal the student's understanding of the concepts discussed in Steps 5 and 1. Student attitudes towards concept mapping and its effect on their learning were also sought.

The procedure for training in concept mapping (Step 3) was as follows:

- (i) Illustration of the key characteristics of a concept map using diagrams familiar to the students: a food web and a classification key (Fraser, 1983, p.53-58),
- (ii) comparison of a concept map and the written paragraph from which it was developed (Novak, 1980, p.ii-8 and p.ii-9),
- (iii) provision of a format for constructing a concept map,
- (iv) individual student production (using the given format) of a concept map based on a hobby or interest, and
- (v) remediation and discussion of the map.

Two basic formats for map construction (Step iii) were tried:

Format 1

- (a) Write down six or seven key words associated with the hobby,
- (b) order these words from most to least important (two or more words can be of equal importance),
- (c) form the words into a map with the most important words at the top and the least important at the bottom, and

- (d) draw lines between words which can be related to each other and write linking words on the lines.

Format 2 was an adaptation of Format 1 based on a procedure suggested by Fensham, Garrard, and West (1981). Here Step (b), the ordering of words, was accomplished by a mathematical procedure. The degree of relation between each pair of words is rated on a 0-3 scale and by summing the relational ratings a total rating is achieved for each word.

RESULTS AND DISCUSSION

Comparison of written and verbal responses

A comparison of student's written reports and associated interviews prior to training in concept mapping (Steps 1 and 2) generated three major findings. Firstly, there were significant inconsistencies between what students had written about the ten concepts and what they revealed subsequently during interview. Responses were classified into five categories: correct, incorrect, ambiguous, incomplete, and no information. An inconsistency involved a shift from one category to another. Fifteen percent of the students showed inconsistency with only one concept, fifty percent with two to four concepts, and thirty-five percent with five to eight concepts. The majority of the inconsistencies involved a shift from a partial, unclear or incomplete written response to a verbal response which was clearly correct or incorrect. Over seventy-five percent of the students revealed at least one clear contradiction between their written and verbal responses. Secondly, neither concept difficulty nor student achievement level was related to the level or type of inconsistency for students in this study. Thirdly, ten percent of the interviewer's interpretations of the students' written responses were subsequently shown to be inaccurate by the interviews.

The major implication from the comparison is that the written responses were not clear indicators of cognitive structure. Students in this study had difficulty in accurately representing their conceptual knowledge in written form. As there was no time pressure, it appears that lack of application and/or lack of fluency in written expression are likely explanations for the results obtained. This problem is compounded by the difficulty in accurately interpreting written responses. Results here suggest that not only do many students have problems with the encoding (expressing their ideas clearly in written form), but also teachers can have trouble with the decoding (accurately interpreting what is written). Take, for example, a written statement on 'formula' by one of the students: "An amount of substances put together".

From this a teacher could easily assume that the student has at least a vague notion of formula as representing "substances" joined together in some way and even some sense of proportions or amounts. However during interview the student showed clearly that he had confused formula with equation. On re reading the written statement in light of the interview, one gets a very different understanding of what was intended.

In summary, if one is to attempt to base one's instruction on what the students already know, as Lovell suggests, it appears that sole reliance on written reports of the type used here would be unwise.

Different methods for teaching concept mapping

All of the students acquired concept mapping skills to a sufficient degree to allow them to draw competent maps. At the same time, a number of the students showed little enthusiasm for the process. It was seen as being a lot of extra work which they would happily avoid. All students trained with Format 2, the mathematical calculation, complained about the tedium of the process. A number of them were at pains to point out how they could order the concepts in much simpler ways. No such complaints emerged from the group trained with Format 1. The maps produced by the two formats revealed no significant differences. The extreme unwillingness of students to work with Format 2 suggests that for these grade nine students at least, Format 1 is the better procedure to use in the classroom setting.

Comparison of concept maps and interviews

Interviewing is widely accepted as a method for revealing cognitive structure. The enormous influence of Piaget and his Genevan co-workers, based on his "clinical method" of interviewing (Oppen, 1974), is convincing evidence of this. The interview techniques used here were based on Oppen's discussion of the Piagetian clinical method (Oppen, 1974) and the adaptation of the clinical method to concept mapping used by Novak and his Cornell group (Pines et al., 1978).

Table 1 shows the number of propositions each student included in the concept map prepared in Step 5, at the end of the unit. A proposition is here defined as "a specific relationship between two or more concepts" (Novak, 1980, p.203). It should be noted that some of these propositions were in fact misconceptions. The Table also shows the percentage of these propositions which were revealed during the subsequent interview (Step 6) - firstly those revealed spontaneously, and secondly those revealed by subsequent probing. The interview was held at least one day after the map was prepared, and up to three days after. Also, no reference was made to the concept map by the interviewer. The degree of agreement between the

TABLE 1

Propositions Revealed by Concept Maps and by Interviews

Student	Number of propositions in map	Percentage spontaneously revealed in interview	Percentage subsequently revealed by probing
K.G.	19	74%	26%
A.N.	17	82%	18%
B.P.	15	87%	13%
L.G.	15	80%	20%
S.G.	15	80%	20%
H.R.	15	73%	7%
S.E.	14	64%	29%
G.M.	13	77%	23%
A.Re	12	100%	-
M.R.	12	83%	17%
P.W.	12	83%	17%
C.V.	10	80%	20%
T.M.	10	50%	-
K.M.	9	78%	22%
S.S.	8	100%	-
N.M.	7	100%	-
K.R.	7	100%	-
J.W.	7	100%	-
A.R.	7	86%	14%
I.F.	7	86%	14%
C.B.	7	86%	14%
K.H.	6	100%	-
P.M.	5	100%	-
C.B.	5	80%	20%

propositions revealed by the students' maps and the subsequent interviews is impressive. In only three cases, H.R., S.E. and T.M. did students not reveal all of their map propositions after probing during interview. The one student who could reveal only 50% of her map propositions, and 'gave up' when probed presented an interesting case. Only five of her ten propositions were correct and four of these were revealed during interview. Even when cued she could reveal only one of her five misconceptions. It appeared that these may have been guesses which were put in to 'pad out' the concept map.

While most students were able to elaborate slightly on propositions in their maps during interview, in only three cases did students reveal significant new information during interview. When questioned about this, one said that he didn't have the space to fit everything in his map, the second had included the information on her 'rough copy' of the map but had forgotten to put it into her 'neat copy'. and the third suggested: "Just didn't think at the time to put it in". In all other cases if propositions central to the topic were not included in the concept map they were not subsequently revealed by the student when interviewed.

These results indicate that in this study concept maps were as accurate as interviews for revealing student comprehension of concepts. The implications of this finding for classroom practice are powerful. Many researchers, for example Lovell (1980), have long advocated the individual interview as the best way to access student understanding. If a more comprehensive study confirmed the results obtained here, it would provide teachers with a very convenient, time-efficient indicator of student understanding for classroom use.

The contrast between the high equivalence of information revealed by concept maps and interviews, and the low equivalence between information revealed by written answers and interviews is worthy of comment. This finding implies that concept mapping significantly helps students to clearly express their comprehension of concepts and conceptual inter-relationships as well as helping the teacher to understand the written student communication. This implication can only be seen as tentative since the comparison of written and verbal answers took place at the start of the topic when students would have been much less knowledgeable and much less confident on the topic.

Student and Teacher Reactions to Concept Mapping

Most students regarded concept mapping as hard work and as an extra imposition, particularly as many of their peers did not have to do it. At the same time, most felt that it helped their learning. For example:

"There's the hard part of working it out, but then you have it for reference - you can just look back for study".

"If you're a poor reader like me the map is good because it's easier to read"

"If you just study with words and writing out paragraphs they seem to just tell you about one thing, but if you're doing it in concept maps you can link it up - you can join it all together with the rest of the subject. It explains that one subject part more thoroughly to help it join in with the others".

This function of helping students pull the topic together and develop a feeling of mastery was commented on by both the students and the teacher. Similarly the development of increased student self-direction was noted by the teacher as well as the students. For example:

"That's happened to me a couple of times - where I didn't understand what the words were where I should have, and I'd look it up in the book and be able to fit it in properly".

"First I see which ones [concepts] go together and the ones left over I look up and find out that they do go with others once I know their meaning".

While concept mapping helped make students aware of gaps in their understanding, the degree to which they took steps to remedy this varied greatly.

The teacher also commented on: the increased "academic self-concepts" of some students; the clarity with which the maps reveal student strengths and weaknesses; and the deeper level of processing encouraged by concept mapping. Marton and Säljö (1976) report that techniques which encourage deep level processing result in higher levels of outcome. The extent to which concept mapping coerces deep level processing is an important area for further research.

CONCLUDING COMMENT

Results from this pilot study suggest that concept mapping has great potential as a classroom procedure for revealing the conceptual understanding of students. It was shown to be as accurate as interviewing for this purpose. Added to this it seemed to have a number of positive effects on student learning.

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EQUATIONS, TRANSLATIONS AND NUMBER SKILLS
IN LEARNING CHEMICAL STOICHIOMETRY

Peter J. Fensham

About a decade ago several researchers and curriculum developers in a number of countries reported that stoichiometric calculations were an area of learning difficulty in some of the new secondary school chemistry courses. However, there was little immediate follow-up to examine more closely what lay behind these difficulties apart from some rather gross comparative analyses of where, in the sequences of the curricula for chemistry and mathematics, apparently mutually relevant skills were taught.

In some countries, such as Britain and a number of other European countries, systematic chemical education begins quite early in the years of secondary schooling. In these cases it has sometimes been found that the quantitative treatment of chemical topics does involve mathematical concepts and skills before they have been introduced in the mathematics classes themselves. An obvious example is the use chemists make of logarithmic functions and their special form of expression in the quantitative chemistry of acids and bases as a p-scale. This quite often preceded the systematic study of logs in mathematics. In the 1980s some secondary school mathematics curricula have eliminated the logarithmic function altogether, and so chemical educators have had to review rather drastically what use they will make of these hitherto common mathematical concepts.

In countries like Australia and the U.S.A. where formal chemical learning begins rather late in secondary schooling there are usually no mathematical concepts or skills which have not been met in mathematics by the time the chemistry curriculum requires them. This does not, of course, mean that there may not be a problem of atrophy of skills. The mathematical introduction of ratio or percentage may precede by several years the chemical use of these skills. More recently there has been renewed interest in this area of chemical learning and a diversity of approaches is being used to try to elucidate its difficulties. Some of these are (a) problem solving, (b) mathematical content, (c) chemical language, and (d) meaning and role of chemical equations.

This paper outlines these rather different research approaches and presents some recent preliminary data that relate to approaches (b), (c) and (d).

PROBLEM SOLVING

Several workers have used a problem solving approach. Herron (1983) has used verbalised learner protocols and contrasted them with teacher protocols. In this way, he has identified a number of sources of learner failure such as inaccurate reading errors in numerical translation, and absence of checks at the various stages of a solution. From a similar study in Holland, Kramers-Pols, Lambrechts, and Wolff (1982) found that teachers and text books often took short cuts in certain stages of their solutions of these sorts of problems and that these were the result of familiarity that learners did not nor could not be expected to have.

Mitchell (1983) found, like Herron, that learners may write the reaction equation at an early stage of their solution attempt but then do not refer to it, as experts do, as a source or check on the other algorithms they set out to use for the subsequent steps in solving stoichiometric problems.

MATHEMATICAL CONTENT

When the solutions of various stoichiometric problems are set out, the succession of mathematical operations can be listed e.g., substitution of value addition of component values, statement of proportional relation, fractional linear equation, etc.

For a number of these component mathematical operations a pair of test items was designed so that an operation was required in a familiar mathematical context and in the context of chemistry. Two classes of students of chemistry (Year 11) were tested on these pairs of items.

Where it was possible to create a similar item in the more familiar contexts of mathematics (e.g., percentage of an element in one of its compounds), no obvious difference was found in the achievement levels. This was true of problems involving (i) ratio, proportion and percentage, and (ii) rank ordering of indices.

When these stoichiometric operations included a step that had no counterpart in the mathematics (e.g., the factor 2 in I_2 that arises from a feature of the chemical concept of molecules compared with 1 atoms, or the pH notation of writing 10^{-13} as 13), the performance of the students on the chemistry item was considerably reduced compared with that on the mathematical counterpart item.

It was found that some quite elementary questions in stoichiometry turned out to be difficult to recast in mathematical contexts, (see A below) and many had far more

steps in combination than would have been practised when those mathematical skills were introduced (B below). For example,

- A. What is the yield of carbon dioxide at S.T.P. when 5g of limestone (CaCO_3) is dissolved in nitric acid?
- B. What is the weight of calcium in 5 g of calcium hydroxide (Ca(OH)_2)? (addition, multiplication, ratio, proportional expression and fractional linear equation).

Thus, it appears that the issue of availability of mathematical skills is much more complicated than the analysis of comparative sequence allowed. Many students of chemistry in Australian schools (and probably elsewhere) do face quite new mathematical tasks as they study stoichiometry which also presents them with a number of quite novel conceptual ideas about chemicals and their interactions.

CHEMICAL LANGUAGE

It has been a common feature of the treatment of many of the new curricula for school chemistry that the "mole" is introduced quite early in the treatment of stoichiometry. This unit for the amount of chemical substance has gained wide international recognition and is often listed as part of the S.I. system with units like the kilogram, second and metre.

A number of the text books for these chemistry courses and numerous papers in the journals of science teaching or of its research refer however to the "mole concept". Dierks (1981b) has pointed to the misconception in the minds of such authors who use such language but who would not refer to the "second concept" or the "kilogram concept". This type of language will he suggests, confuse students and detract from the need in chemistry to invent a concept, other than mass or volume, that expresses an amount of substance in a way that maintains the atomic view of matter and easily relates to how substances interact.

Our own awareness that language issues may be influential in these topics in chemistry arises from preliminary interviews with students about the reacting systems that consist of zinc or magnesium metal dissolving in hydrochloric acid. The context for these interviews was set by the researcher, in the presence of the student, placing about 10 ml of hydrochloric acid in a test tube. A small piece of metal was then added to the acid and the test tube was then given to the student with the instruction to observe it carefully. (The acid concentration was chosen so that complete solution of metal occurred in about one minute.)

When the reaction had ceased the students were asked a series of questions and their answers were probed to elucidate the meaning of the words they used. For example, some students used the word "disappear" to describe what happened to the metal. Some of these, on probing, were using it synonymously with "dissolving" or "going into the acid" while others were "not sure where the metal was now" or "thought it may have turned into the heat that was generated".

A summary of some of the commonalities of the responses from the small numbers (6-10) of students interviewed at random from Victorian secondary school classes in each of Years 10, 11 and 12 is given in Table 1. Some of the Year 10 students were not familiar with equations or all the symbols for the chemicals of this reaction but most of the Year 11 and 12 students were able to write the equation and balance it.

TABLE 1

Some common responses from students in different year levels
to the reaction of magnesium with dilute hydrochloric acid

	Year 10 (15+)	Year 11 (16+)	Year 12 (17+)
<u>What do you observe?</u>			
droplets up tube			
tube gets warm		(sometimes)	(sometimes)
metal disappears		Magnesium dissolves	Magnesium dissolves
bubbles of gas		Hydrogen bubbles	Hydrogen evolved
<u>Where does gas come from?</u>			
metal		acid	acid
<u>Where does metal go?</u>			
dissolves		dissolves in acid	dissolves in acid
not sure		-	-
disappears		-	-
seems to turn into bubbles		-	-
<u>What has happened to acid?</u>			
nothing		used up	some has reacted
looks same		contains Mg^{2+} ions	contains Mg^{2+} ions
contains metal		-	-

Much more data of this sort need to be collected (and with greater planning than in this investigation) before the discussion that follows has more than speculative worth. With a clear acknowledgement of these limitations a number of features of these interviews do stand out.

There is a marked shift with the years of chemical learning to a more limited interpretation of what the word "observe" means.

References to the droplets of water that obviously condense on the upper walls of the tube or to the warming of the bottom of the tube were common with the Year 10 students but almost absent in the reports of the Year 11 and 12 students.

The Year 10 students reported their observations (and indeed these were accurate observations) about the metal and the acid: "the gas comes from the metal" or "the metal seems to turn into gas bubbles" and "the acid looks the same" or "nothing has happened to the acid".

On the other hand, the Year 11 and Year 12 students reported statements which seemed to be recitation of verbal descriptions provided by teachers as being the "chemical knowledge" of this reaction: "the gas comes from the acid" or "the magnesium dissolves" and "the acid now contains the magnesium as ions".

These shifts reflect what would normally be considered to be chemical learning but they can also be used as an indication of what may be a quite basic feature of the language of the teaching of the "chemical knowledge" accorded worth in most curricula. In other words, the knowledge of worth in chemistry is a received language the meaning of which is found in a realm of unreality or abstraction that does not co-incide with the reality of the observable. This claim is not surprising when one is considering quite deliberately conceptual aspects of chemistry such as "the action of the hydrochloric acid is as a proton donor". It was, however, surprising to the author as researcher in these interviews since they seemed to be concerned with such a factual situation in chemistry.

There was the possibility that this "jump away" from the beginning learners' accurate statements of observations was a more general feature of the language code of taught chemistry. This was explored a little further by looking at the way these systems are described in text or examination items. A question about the source of the gas in elementary chemistry did expect the answer to be "the acid", although it is observationally and synthetically incorrect, (since electrons, half the constituent entities of the hydrogen come from the metal). As soon as quantitative chemistry is introduced (usually quite early in the learner's experience of chemistry in Victoria),

these sorts of systems are tested by questions such as, What is the yield of hydrogen gas at S.T.P. from . . ? or, x g of magnesium is dissolved in y cm³ of hydrochloric acid of a given molarity, what is the amount of the excess reagent?

Here again, another interesting example of the possibility of the received language code may be cited. If it is the metal that is in excess the student usually is to select between four answers all of which are an amount in grams. However if the acid is in excess the four alternatives are now all amounts with the unit mole although the original question presented the amount of acid in cm³ - the observed reality. It is intriguing to think how the correct answer to acid excess could be expressed if one maintains its original description - zero cm³ of the original acid y cm³ of a more dilute acid, y cm³ of a diluted acid containing Mg²⁺ ions?!

These examples of the language of chemical neonates and of taught chemistry conjure up some interesting possibilities. If the traditional taught language is, say a collection code in the sense that Bernstein (1971) used the term, how would these systems be described in a chemistry for neonates that used an integrated code?

Perhaps we would have instead multiple choice questions in which most or all of the multiple choices would be correct answers in some meaningful chemical sense.

Q. Where does the gas come from?

- A. (i) the acid
- (ii) the metal
- (iii) the metal and the acid interface
- (iv) the metal seems to turn into the gas bubbles, etc.

Q. What happens to the acid?

- A. (i) nothing, it looks the same
- (ii) it dissolves the metal
- (iii) it now contains the metal as ions
- (iv) it has been diluted or been used-up

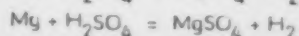
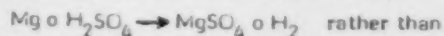
MEANING AND ROLE OF CHEMICAL EQUATIONS

In the last two years five reports of research can be cited that focus on the meaning and role of the reaction equation in these calculations.

Weninger (1982) and Dierks (1981a), both at IPN., on the basis of school evaluations of alternative curricula have diagnosed several problems and recommended improved methods of teaching the quantitative topics in chemistry.

The former has found that the conservation of atoms is useful as a rule in balancing equations but does not relate to their fundamental information. Only in the sense of this conservation do chemical equations have the property of equality that the sign = has in mathematics. Too great a stress on this balancing rule can obscure the meaning that a chemical equation provides about the actual substances involved. Accordingly, he recommends the use of the direction sign for the idea of "yields" or "converts to" which is also coming in to mathematics in Germany when the operational process is under emphasis, e.g. $2 \xrightarrow{+4} 6$ meaning 2, when 4 is added converts to 6. Compare this with $2 + 4 =$ (is the same as) 6.

He has also recommended a move away from the usual "plus" sign replacing it with a "bringing or tie-ing together" sign, "o", and dropping the term "reaction equation" for "reaction symbol" or "conversion symbol" e.g.



Dierks (1981a) goes on to argue that a further advantage in doing this is that it is easier from this form to recognise that these symbols represent the proportions in which these substances react and form products together. That is, this form is less likely to lead to the common confusion that the symbols in the equation are the weights of substances that interact in this way. His paper illustrates the usefulness of this distinction in a number of cases.

Yarroch (1982) at Wisconsin has carried out interviews on a better than average group of school chemistry students. He found that they all had the skills to balance four fairly simple reaction statements but only a minority were able to relate the rules they used to chemical meaning or to draw pictorial representations consistent with the chemical meaning of the reactants and products. This finding tends to support the claims of Weninger.

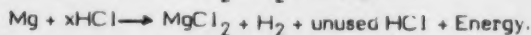
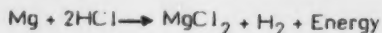
Andersson and Renstrom (1982) at Goteborg have found that a large proportion of Swedish students do not axiomatically conserve mass or atoms in chemical change. Mitchell (1983) has reported a similar finding in a broader study of stoichiometric problem solving among students in a Victorian school.

Our own investigations of students understanding of the reaction equation for the solution of a metal by hydrochloric acid indicate that knowledge of chemical equations appears to be acquired in an evolutionary manner (see West Pines, and Sutton (1983)). That is, their comments very much reflect the particular teacher's emphasis and there was no evidence that extra-schooling cognitions were influential.

This can lead in some students to statements that "all the atoms need to appear on both sides" and "you count them up to see that they are equal" - conservation of atoms algorithms. When these statements, however, were probed, or other features of the reacting system were discussed, similar findings to Yarroch, Weninger, and Andersson et al were found in several students. Thus, products for a reaction could be suggested by analogy with previous experience that involve species not present among the reactants. Again if a reaction is exothermic there are some students who seem happy with the idea that this may be the result of the conversion of some reacting matter into energy.

In the interviews about the chemical equation for the reaction of metal dissolving in hydrochloric acid, the students were asked and probed about such questions as, What does a chemical equation tell us?, Why is it called an equation?, Is the equation (the balanced one) a good description of what has just been observed?

Where an answer to the question, Why the term equation?, was given it was usually in terms of a count of the atomic types on each side. The students were later offered two other equations:-



After the students had repeated the reaction they generally agreed that these were better descriptions of the system in hand.

A pertinent comment about the second of these formulations of the reaction statement was, Why doesn't the teacher ever write equations like that since they seem to be better descriptions? Perhaps this is both an example of the received language and the short cutting to which Kramers-Pols et al. (1982) above have referred. This second equation with its direct description is implied but not explicitly stated when text books and teachers solve these problems.

Acknowledgements

The author wishes to thank David Symington, Jan Garrard and Gloria Dall'alba for their help with preliminary interviews and data collection.

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AN INTERVIEW STUDY OF RESPONSES TO DIAGNOSTIC, MULTIPLE-CHOICE, PHYSICS ITEMS

Colin Gauld and Kathryn Ryan

INTRODUCTION

Over many years considerable effort has been expended in studying those characteristics of multiple-choice tests which affect the final score obtained by students. However the factors which seem to gain most attention are formal characteristics of tests such as the number of alternatives, the position of the correct alternative, the order of difficulty of the items and the effect of violating item construction principles. Little interest seems to have been shown in exploring the cognitive processes used by students to answer the questions and in disclosing how these processes are related to the alternatives finally chosen.

When a student responds to a multiple-choice item the selection of the 'correct' alternative is used by the tester as an indicator that the appropriate cognitive process has been correctly used. Knowing something about the way appropriate processes can be used to obtain wrong answers and how inappropriate strategies can lead to correct responses helps to provide a more valid interpretation of test results. Such knowledge is also essential when multiple-choice items are used as diagnostic tools, for here the whole purpose is to distinguish adequate from inadequate procedures so that suitable remedial work can be assigned. Effective remediation usually depends on having detailed knowledge of the types of errors that are being made and these have to be inferred from the alternatives selected by the student.

THE PRESENT INVESTIGATION

The study reported here is an attempt to explore this area using a group of expertly constructed, multiple-choice, diagnostic, physics items and adopting the subject-(or student)-oriented perspective discussed elsewhere (Gauld, 1980).

Previous investigations of the processes which lead to responses in objective test items have used either a 'think aloud' technique (Bloom & Broder, 1950; Kropp, 1956; McGuire, 1963; Connolly & Wantman, 1964; Hateley, 1979) in which the subject describes what she is doing as she does it, or a retrospective interview (Cox, 1976; Gauld, 1980) after the item has been completed under more or less normal test conditions.

In the present study items were completed before an interview so that responses made under normal test conditions would be available. Also information could be gathered about strategies and concepts that were possessed by the student but which were not used in responding to the items as well as about those that were used.

THE PROCEDURE

A twelve-item test was constructed to simulate the core multiple-choice section of the New South Wales Higher School Certificate examination and the items were chosen from the Physics Unit Tests published by the A.C.E.R. (1978). Specific items used are listed in Table 1. An attempt was made to cover all the major topics in the core and to vary the nature of the items so that some could be solved by simple recall while others required more complex cognitive activity; some used graphs or diagrams while others used only words; and some required the student to answer a question while in others a sentence was to be completed.

In the first instance the test was taken by about one hundred Year 12 pupils in order to calculate item facilities and discrimination indexes, and the internal consistency of the test. These are the parameters by which tests and items are usually described from the tester-oriented perspective.

Eighteen boys and eighteen girls from Year 11 classes were individually asked to complete only four of the questions after which they were interviewed. This was to ensure that the interview questions were answered soon after the choice of multiple-choice alternatives was made so one could have more confidence that answers to interview questions described the actual state of affairs which existed during the response to the multiple-choice items. Each of the 12 items was answered by twelve students so that in all 144 student-item pairs were obtained and analysed. The total time required from each student was about 30 minutes.

Overall the pupils were asked about the item content in a number of different contexts.

- (a) They were asked to choose the alternative which they thought to be correct (or most correct) for the four multiple-choice items.
- (b) They were asked to explain the choice they made for each item.
- (c) They were asked to explain why other alternatives were rejected.
- (d) Those who had not used an appropriate strategy were given cues designed to determine whether they possessed such a strategy but did not use it.

During an interview there is the possibility that students reconstruct rather than recall the procedures by which multiple-choice alternatives were chosen. Thus the interview data are probably a better indicator of the strategies available than of those actually used.

RESULTS

For the preliminary group of one hundred students the item statistics listed in Table 1 show a range of difficulties and under normal procedures of test construction some items may have been rejected because they were too easy (1, 3 & 4) or too difficult (10). All items possessed a positive and satisfactory level of discrimination.

TABLE 1

Item Facility and Discrimination Index

Item Number	ACER Item		Discrimination Index	Facility
	Test	No.		
1	3	17	0.52	0.81
2	2	13	0.12	0.69
3	5	10	0.43	0.80
4	5	23	0.29	0.90
5	6	5	0.40	0.57
6	7	7	0.57	0.33
7	15	20	0.52	0.74
8	8	17	0.38	0.66
9	18	14	0.76	0.53
10	19	14	0.48	0.19
11	19	6	0.43	0.71
12	10	15	0.76	0.36

The test as a whole possessed a KR-20 internal consistency of 0.59 which is probably typical of good, teacher-constructed tests of this length and which cover a wide range of topics.

The test-interview data are summarised in Table 2 to show the relationship between the response chosen and the possession of an adequate strategy as revealed during the interviews. An appropriate strategy which could be used without error or with only 'insignificant' errors was considered to be an adequate strategy. Misconceptions, errors in application of knowledge, and lack of some types of conventional knowledge were considered to be significant errors because they were directly related to the general physics content of the item. Incorrect assimilation of information, mathematical errors, and lack of some types of conventional knowledge were considered to be insignificant errors.

TABLE 2

Relationship between Availability of Adequate Strategy
and Choice of Correct Response

Strategy Available	Response Selected		Total
	Correct	Incorrect	
Adequate	65	23	88
Inadequate	12	44	56
Total	77	67	144

Table 2 refers to four types of data, and some comments about each of these follow.

1. Adequate Strategy: Correct Response

Of the total set of 144 student-item pairs interview data showed that in 88 instances students possessed all the elements of an appropriate strategy but in only 64 cases was this strategy used correctly to obtain the correct answer. For one item (4) a student who possessed an appropriate strategy claimed to have guessed the correct answer.

Analysis of the data for this group of 65 student-item pairs showed that for two of the 12 items (4 & 6) each student appealed to one of three distinct but appropriate strategies to arrive at the correct answer, for four items (1, 2, 10 & 11) those responding in this way used one of two distinct but appropriate

strategies, and for the remaining six items only one strategy was employed in each case.

2. Adequate Strategy: Incorrect Response

Of the 23 student-item pairs for which students possessed an adequate strategy but chose an incorrect alternative in five cases students realised their error during the interview before any cue was given while in eight instances they were able to choose the correct alternative after being provided with fairly insubstantial cues. For the remaining 10 student-item pairs students used appropriate strategies but with insignificant errors which persisted throughout the interview.

3. Inadequate Strategy: Correct Response

In seven student-item pairs of this group of 12 the correct answer was arrived at by using a well-defined but inadequate strategy; in three cases such a strategy was used to eliminate one or two of the alternatives after which the students chose randomly from the remaining alternatives, while in the other two cases the students guessed from all four alternatives. In six cases appropriate strategies containing significant errors were used, while in the remaining six cases the strategies were not appropriate for the items.

4. Inadequate Strategy: Incorrect Response

Twenty-six cases in this group of 44 represented use of a well-defined but inadequate strategy, two were guesses from a reduced range of alternatives, while 14 were guesses from all four alternatives.

DISCUSSION

The Diagnostic Function of the Items

A good diagnostic item would be one for which the choice of a particular alternative was a good indicator of the process used to arrive at this alternative. Two of the twelve items (8 & 10) functioned well in this sense. The first discriminated between those who believed that electric current was used up as it passed around an electric circuit and those who did not. The second item required a correct conception of the direction of an induced current as the magnetic flux changed, together with a correct application of the relevant hand rule. Errors could be made in either or both of these components and the alternatives discriminated between students using each of the four resulting combinations.

Five of the items (1, 5, 6, 7 & 12) appeared to be poorly constructed while in others the alternative chosen did not indicate clearly enough the process used to arrive at that choice.

The Influence of the School Context

The multiple-choice test requires a response to be made in a strongly school-related context. During interviews there was a great deal of evidence that students had used strategies which appealed to what they knew about this context rather than simply to what they understood about the subject matter. Some who arrived at an alternative that was not available re-worked the problem while others just guessed. Some remembered formulae which they did not understand and quite a few referred to things that they remembered from physics lessons.

CONCLUSION

In three-quarters of the student-item pairs the multiple-choice items correctly identified the use of adequate or inadequate strategies so on a general level the items might be thought to have performed satisfactorily. However as diagnostic tools they were generally inadequate and this fact points to the desirability of using the student-oriented procedure for constructing such items. In this procedure student understanding of the domain of knowledge is probed through interviews and distractors are designed to reflect the dominant types of misconceptions.

The importance of the school-related context was something which emerged during the interviews and, in the light of the discrepancy between student understanding as revealed through school tests and interview studies, this is an area to which more attention needs to be given.

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ARROWS IN SCIENCE DIAGRAMS: HELP OR HINDRANCE FOR PUPILS?

Brendan Schollum

INTRODUCTION

The work of Ausubel (1968), Driver (1981) and others suggests strongly that children coming to science classrooms have already formed views about the natural and technological world around them. Similarly, one of the major outcomes of the Learning in Science Project (Osborne, *et al.*, 1982) was that children do bring to science lessons strongly held views about why and how things behave as they do and that their views appear to them to be sensible and logical. Unless teachers identify the views that children hold and design their teaching accordingly, some children's ideas will not change, or will change in unanticipated ways as a result of formal science teaching.

Is the above situation true of children's views of science diagrams as well? From a colleague's study of textbooks commonly used at the Form 3 and Form 4 level (13-14 year olds) it was found that arrows are used in diagrams at an average rate of one every three pages. As well, arrows were used in these distinct ways:

- (a) as labels;
- (b) for measurement;
- (c) as forces (other vector quantities were not used at this level);
- (d) to illustrate relationships such as energy transfer or matter classifications;
- (e) to represent changes in chemical reactions;
- (f) for sequence in time and/or space.

Sometimes arrows served two functions within one diagram.

The purpose of this study was to investigate and describe how the presence of arrows in science diagrams influences pupils' interpretations of these diagrams. In order to do this it was important to determine children's views of several different diagrams which did not contain arrows before introducing similar diagrams that did contain arrows. The latter group of diagrams were all taken from science textbooks.

SUBJECTS

The investigation took the form of a series of tape recorded interviews with individual children who were all in Form 4 classes. Fourth Form pupils (14 year olds)

were chosen because they should all have covered the topics from which the diagrams were chosen. All pupils were from average ability classes though one pupil was outstanding for the clarity of his expression and another pupil seemed bewildered by the experience. This may have been due to extreme shyness rather than a lack of an ability to verbalise the most straightforward of ideas or explanations. Of the fifteen pupils interviewed, eight were female. These have been given odd numbers 01 to 15 while males are coded using the even numbers 02 to 14. The pupils came from both single sex and co-educational schools in Auckland.

PROCEDURE

The pupils were withdrawn from science classrooms one at a time, and the interviewees were helped to relax by some initial conversation about his/her schooling and interests. The purpose of the interview was explained and this was that the interviewee had been chosen as one of a number of fourth formers from various schools to talk about several different science diagrams. It was their views that were wanted. Also, the purpose of having the tape recorder was explained.

Each diagram (see Appendix A) was presented one at a time, with a brief comment to help set the context of where the diagram had come from: e.g., for diagram 1, two comments such as "Here is a diagram that you might have come across in a chapter on 'Communities'". Each pupil was asked "What does this diagram mean to you?" or "When you see a diagram like this what does it mean to you?". The pupils' meanings for words used or seen in the diagrams were explored as well as their overall view of each diagram.

Once the cards of diagrams without arrows (diagrams 1-5) had been completed, the five cards of diagrams with arrows (diagrams 6-10) were used with words such as "Now let's look at this diagram, it's from a chapter on 'Communities'. What does this diagram mean to you?". Thus each pupil made comments about ten diagrams. This procedure has been adapted from a method developed by Osborne and Gilbert (1980).

Each interview, which normally lasted about 20-30 minutes, was audio-taped and later transcribed.

DIAGRAMS OF FOOD CHAINS

(a) Without arrows

When the two diagrams of food chains (cards 1 and 2 in Appendix A) were presented to the pupils, every pupil except one (01) was able to explain clearly what each diagram showed. These examples indicate the views expressed:

'It's showing a food chain. The herbivore is living off the tree. The bird looks for food in the tree also (What sort of food?) I'm not sure. (And what about the cat?) It's a scavenger; it's looking for food. (Could it find its food from anything in this diagram?) No'. (01)

'It's really showing the life cycle of plants. The bugs eat the bush. The birds eat the bugs and the tiger eats the birds and they don't know it but they've got all these different things in them - in their system. That's not counting waste products of course ... The waste products contain seeds so more plants grow'. (09)

'I think the bird would eat all these insects. The caterpillar would eat the cabbage. I'm not sure if birds eat spiders but it looks as if they do'. (10)

(b) With arrows

However, when these diagrams were re-introduced (cards 6 and 7) there was a wider range of views expressed and less confidence in the views that were expressed. For half the pupils, the diagrams were outright puzzling:

'This looks like the cabbage is going to eat the caterpillar and the caterpillar is going to eat the bird. This diagram doesn't look right'. (02)

'It's telling me something that I wouldn't believe. It suggests that a spider eats a bird, or a caterpillar eats a bird which I think is impossible and a cabbage would hardly eat a caterpillar. Those arrows are around the wrong way for a food chain'. (05)

'It's showing the opposite of what really happens. It's showing that the producer provides for everything. The insects get bigger and they provide food for the birds'. (12)

The other pupils gave various meanings for the relationships between species in the food chain. Words such as 'lives off', 'produces', 'depends on', and 'is eaten by' were used to explain the diagrams whereas in the earlier cards nearly every pupil used the term 'eats'.

One pupil (01) continued to be confused:

'This one's about the sun's energy ... The plant and the herbivore are somehow connected. I'm not sure how. The scavenger is up here looking for food. (In the diagrams or pictures here or somewhere else?). Somewhere else'. (01)

Other than the obscure comment from pupil 01 above, no pupil spoke about energy flow in a food chain in the direction of the arrows. For half the pupils the presence of arrows introduced a confusing element into their understanding of the diagrams of food chains.

MATTER CLASSIFICATION DIAGRAMS

(a) Without arrows

Diagram three (see Appendix A) was introduced with words such as 'This is a diagram from a chapter on "Substances" or "What Matter is made of"'. A few pupils expressed their views clearly and readily but the majority of the pupils found some difficulty with the diagram probably because it was less familiar as an example than the previous diagrams discussed. The following views were expressed:

VIEW 1 These pupils (02, 03 and 09) held the view that the diagram was a method of showing that examples of matter were partly living partly non-living, and that these parts were composed or made up of molecules and atoms.

'Matter is made up of living cells and non living crystals and both of them are made up of molecules which in turn are made up of atoms. (What are examples of matter?) Insect - an insect is made up of living cells and non living cells and part of us - probably the waste products are the non living part, the things we don't use. The living cells are the part that help us to breathe and see. (Would paper be an example of matter?) No because it doesn't have living cells.' (09)

VIEW 2 Seven pupils (05, 06, 07, 08, 10, 13, 15) had the view that the diagram was a way of showing that examples of matter are either living or non living and both of these types or categories of matter are made up of molecules and atoms.

'Matter is, ... can either be non living which is crystals or it can be living which has cells, and they both have molecules made up of atoms'. (07)

VIEW 3 Two pupils (04 and 11) had the view that the diagram represented a life cycle for matter.

'It's what matter turns into when it changes. It's like a cycle. Matter changes into living things. (What are some examples of matter?) Therefore the air. Things that are in the air are matter (Tell me more.) There are living cells in the air (Carry on.) other things that are in the air are as small as atoms (What is in the air then?). Lots of things, some of them are as small as atoms. Others are living cells. (What about this other part of the diagram?) This shows what they go to when they die. They go to crystals, they evaporate; go to nothing'. (04)

OTHER VIEWS The other three pupils, (01, 12, 14) were not sure really what the diagram meant. They had difficulties in verbalising any relationships between parts of the diagram and definitely had no clear idea of what the whole of the diagram meant. There were parts of the diagram explained but no clear view emerged. For example, pupil 14 said among other things:

'Molecules are little parts of substances in science. Living things are in cells, things like bacteria. Nothing lives in crystals. There's no connection between crystals and molecules. (What does this word matter mean to you?) Matter refers to things that are living. (For example?) The sun and heat'.

(b) With arrows

When the discussion focussed on the diagram with arrows (diagram 8) the views expressed were generally similar to those expressed earlier. Most of the pupils explained their view more easily and this may have been because of the presence of the arrows or just the fact that they were more relaxed by that stage of the interview. For the purpose of comparison consider what each of the pupils whose comments were used in the section above said about the diagram with arrows.

VIEW 1 'This diagram is the same one as we saw before'. (09)

VIEW 2 'Matter can either be non living which are crystal, which are made up of molecules and molecules are made up of atoms. Or matter can be living which is made up of cells which are also made up of molecules'. (07)

VIEW 3 'It's sort of like a life chain but it involves things you can't see, the micro-organisms. You can't really see them but this shows the cycle they go through. (Tell me about it.) This is matter living in little cells ... they all go down to molecules and atoms. These become non living crystals when they die. It depends what you are talking about. You can't say a tree is living in the sense that it's living in its own world. It is living in that it has living cells which are made up of molecules. Once the cells die, you get crystallisation, you have non-living crystals formed'. (04)

OTHER VIEWS With arrows present pupil 01 held a view consistent with category 2 above; she explained that matter is made up of living cells or non living crystals, and that cells and crystals are made up of molecules and atoms.

Pupil 12 held a view that the matter is in both living cells and non living crystals and when these break down 'later on' molecules and atoms are formed. The arrows were seen as expressing sequence in time.

The third pupil, 14, held a different view from that expressed earlier, but still an idiosyncratic view related to energy flow and time.

'All the matter, all the energy goes that way (pointing in direction of arrows). The living cells get energy from matter and they form into atoms. The non living things get energy too. They form into crystals which then form into molecules when they break down'.

CAR DIAGRAM

(a) Without arrows

Card number 4 was introduced with words such as 'This diagram might be found in a chapter on Forces. What does it mean to you?'

Most pupils immediately began talking about a specific section of the diagram, often merely saying out loud the words shown on the diagram with little explanation. Only one pupil used the term 'force' in describing the diagram. The majority of pupils had the view that the terms shown were labels to help show how the car works, or properties of the car. The function or purpose of the labels varied as follows:

VIEW 1 Six pupils regarded the diagram as showing how the car works. Other expressions used were 'how the car reacts' or 'how fast the car goes'.

'It's showing how a car works. Friction and the weight keeps the car on the road. The driving force is what keeps the car moving. The reaction is that when the car is going it's the exhaust gases'. (14)

VIEW 2 Four pupils mentioned that the diagram showed properties or characteristics of a car.

'It shows what the different science points are on a car. Things relating to science. (Where is the wind resistance you spoke about earlier?) Round the back - near the driving force. (How are the wind resistance and the driving force connected?) The driving force is the wind pushing out of the way and wind resistance comes from round the back of the car and makes it go a bit slower ... (What about wind resistance and friction. How do you think about those?) Friction is more to do with tyres. But the wind isn't'. (04)

OTHER VIEWS Another pupil (08) explained that the labels represented forces present when a car is moving and was scientifically correct in explaining three of the four forces. He was not clear about the reaction force.

A further pupil (10) considered that the terms shown were all to do with gravity and he supported his view with the observation that gravity acts in all directions around the car.

Another pupil focussed on the word reaction and explained the diagram represented what would happen if a potential collision was to be avoided.

'This shows the reaction that would happen if you saw a car coming towards you. There'd be friction because of the car's movement. The driving force is the speed the car is going and the weight is how heavy it is. You have these things happening and you react to them. That's the reaction'. (12)

Two pupils' views were not easy to describe.

(b) With arrows

When diagram 9 was used six pupils gave basically the same view previously. Another four of the pupils were able to give more information about the diagram, even though their views were not necessarily scientifically correct.

'This one looks a bit different. Yes, it's got arrows now. It shows the car is going ahead and the friction is coming towards it. The reaction is from the top and the weight is below it. (What do you mean by weight?) It's showing that the mass of the car is on the road. The weight of the car is felt by the road. (laughs) I know that sounds stupid. It's showing that the weight is not upwards. The car is not lifted. (What about the term reaction?) It's just the wind. The wind goes up and over the car'. (09)

'This isn't like the others (cards 1 and 2). This is a science one. (What are the others like?) They are more human ones. This one is science technology. The car is man made. (Tell me about this.) This shows all the forces on the car. (What do you mean by 'forces'?) The strains on the car. Not really how the car works but the reaction points ... the friction is to do with the tyres and the wind resistance goes over the car. It depends on the driving force. (And what about the driving force?) The wind might come over the car then come round and push like in little circles ... gravity holds the car to the ground so it reacts to the ground. (04)

Three pupils were confused by the presence of the arrows. One (08) had previously been the one pupil who had clearly explained the correct function of the labels as forces. But with this diagram he was not happy.

'Basically the arrows are all in the wrong place. The driving force is pointing towards the car whereas it should be coming away from

the car repelling it. Friction is just blindly pointed at the vehicle, it should be pointing downwards at the point of contact of the vehicle and the road. The weight is right. The reaction is wrong too it should be pointing towards the vehicle because the reaction is when the driving force is overcome ... This diagram is explaining that the car is stationary. The other shows the forces when the car is moving. This one just leaves you to make up your own mind.
(08)

The other pupil was still not clear about this diagram.

With both cards (4 and 9) the pupils were asked if the car was moving. Their answers are tabulated.

Diagram	Is the car moving?	
	Yes	No
4. Without arrows	12	3
9. With arrows	11	4

Pupil 08 was the only pupil whose view changed and his reason is given above.

EARTH'S GRAVITATIONAL FIELD DIAGRAM

(a) Without arrows

This diagram was introduced with a comment such as 'this diagram has "Fig. 18.1 The Earth's Gravitational Field" written under it and might be found in a chapter on Gravity, or Earth's Gravitational Attraction'. The diagram was initially confusing to most of the pupils interviewed because of its similarity to diagrams depicting the sun. Thirteen of the pupils made comments that the diagram looked like a diagram of the sun. Five of these pupils then spoke about what the diagram meant if it was the earth shown. These five pupils and the other two (08, 12) who spoke only about the earth's gravitational field had various ways of explaining what the diagram meant to them. Three quotes are given to illustrate this variation:

'In a way it just looks like the sun ... Otherwise it could be the earth and it just gravitates out from the middle. The gravity goes out and pulls in. (What do you mean by gravity?) I always think that gravity comes from the middle of the earth and pulls in so we can stand rather than float up and around. It pulls things towards the surface but not right in'. (11)

'This one is explaining the strengths of the earth's gravitational field. The lines that are longest and most spread out show where the gravitational field is strongest. The others show where the gravitational field is weaker ... The earth's gravitational field is its gravity, the pull in towards the centre of the earth'. (08)

'Those lines show that gravity is all around the earth. Like when you jump up and come down'. (10)

(b) With arrows

All fifteen pupils spoke about the earth's gravitational field or gravity. The presence of arrows was a clear indicator, along with the introductory comments from the interviewer, that the earth was obviously represented by the circle on the page. The arrows represented gravity pushing or pulling, or staying on the earth's surface because of the spin of the earth. These views were expressed:

'That suggests to me that something from the inside is pulling something from the outside. (What is the something?) It's shown by the arrows. It's gravity whatever that is ... (What is meant by this term "earth's gravitational field"?) How much can be pulled in over a certain area. The arrows show that things come in from a wide range'. (05)

'This is the gravity pulling into the earth. As it's spinning round it's got things pulling into it. (What sorts of things?) It's not really things being pulled in, it's just that things stay on the earth and don't float away. (Things like what?) Oxygen, us. Gravity is the spinning rotation which holds us. If the spinning stops we'd all float away'. (04)

'That's explaining the gravitational field. The force that pulls everything in towards the centre of the earth. It's showing the

longer and more widely distributed arrows are the areas of greatest gravity and the smaller ones show the less. This one has arrowheads and that's helpful'. (08)

As well two questions were asked to each pupil as part of this section of the interview.

Question	Answers given	Yes or Yes, but less than on earth	No	Not sure
Is there gravity in space?		7	7	1
Is there gravity on the moon?		10	4	1

These questions were used to help clarify pupils' views about gravity (or earth's gravitational field) extending to places not shown by the arrows in the diagram.

DISCUSSION

The description of pupil's views for the paired diagrams has highlighted some significant differences. However, in over 10 per cent of the responses given for diagrams containing arrows, pupils clearly indicated that the diagram itself was the same as the earlier equivalent diagram discussed. In these instances the pupils considered that there had been arrows in the earlier diagram. For example:

'There isn't anything different from before. The arrows are still pointing the same way'. (03, Diagram 8)

Several of the terms found in the diagrams have been investigated in greater depth in other studies. Stead (1982) and Brumby (1982) have investigated children's understanding of the concept 'living'. Thus it was not surprising to find children in this study who gave air, oxygen, heat, water or the sun, as examples of matter that was living for these views and others were also found in the two studies referred to. Stead and Osborne (1981a) explored children's views of gravity. They found that children's views of gravity being caused by the air pushing down, or the earth spinning are by no means uncommon. These views were also expressed by pupils in this study. Stead and Osborne (1981b) also investigated children's views of friction and Schollum (1982) found there was variation in the way the term reaction was understood and

used, in a study of children's views of chemical changes. A similar range of views occurred when pupils focussed on the term 'reaction' in diagrams 4 and 9. The five meanings obtained for the term 'reaction' were:

- . movement upwards
- . response to a physical stimulus
- . the mixing of two substances causing change
- . waste products (the exhaust gases)
- . another way to tell that the car is moving.

Thus the range of views was similar even though the stimuli for eliciting views varied throughout the investigations referred to.

In instances when pupils' views changed once the arrows were introduced to diagrams (cards 6-10) some pupils interpreted the arrows in ways not intended by the textbook authors. This is not surprising where there are six distinct uses for the arrows, commonly found in science textbook diagrams at this level. For example, several pupils had the view that the arrow upwards in diagram 9, showing the reaction force, actually denoted movement upwards. Similarly the arrows in diagram 10 denoted movement of substances towards the earth's surface. As one pupil said:

'It shows that the gravity is going in. Everything is going down because of gravity. (What sorts of things?) Everything. When you let something go, it drops down'. (07)

Finally, the emphasis in this study has been on the presence or existence of arrows in science diagrams, and not on their sizes, shape or position. Isolating these factors would require further investigation. However, as has been seen (above) pupils were distracted by the position of arrows in some of the diagrams.

IMPLICATIONS FOR TEACHERS

Osborne *et al.* (1982) found that some of the views held by pupils seem to be particularly resistant to change, or be influenced in unanticipated ways, by science teaching. In a related study Schollum (1981) found that children often interpreted science diagrams to fit the views they held about the particular concepts or topics involved in the diagrams. For example, 80% of 12-14 year olds (N = 416 total) do not hold the view that there is nothing between the particles of gas in air. When a diagram of a gas is drawn showing particles spread wide apart, then many children rationalise the diagram and their own views by thinking that 'the teacher (or writer) has not bothered to draw in everything'. Teachers must respond to this possibility by

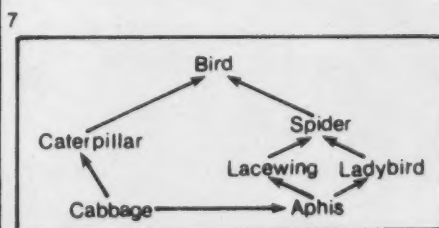
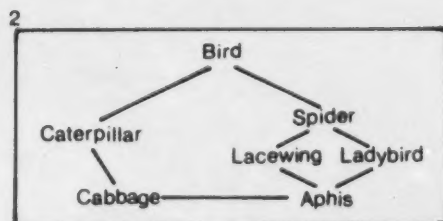
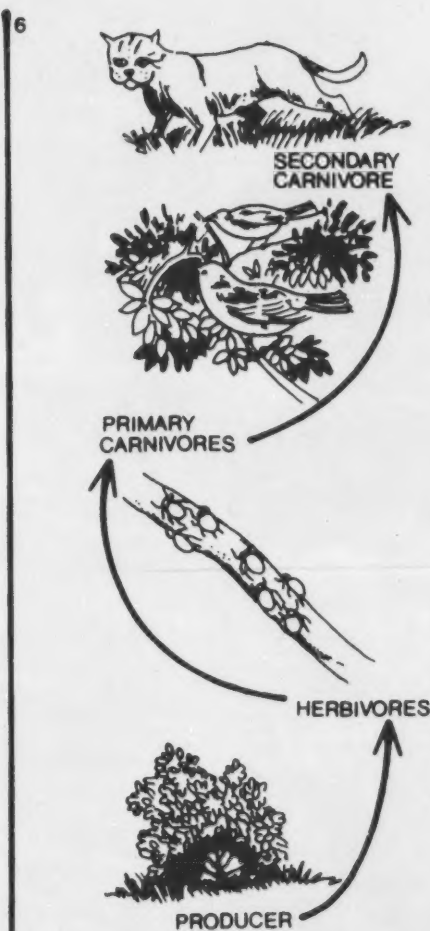
explaining diagrams carefully and to do this they must be aware of the views that children hold.

In a similar way, to prevent confusion arising or being reinforced when diagrams containing arrows are used, teachers need to be aware not only of the variation in the ways arrows are used but also of pupils' views about these types of diagrams.

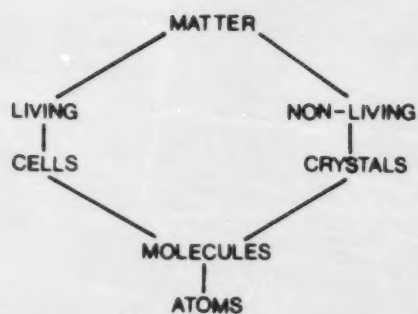
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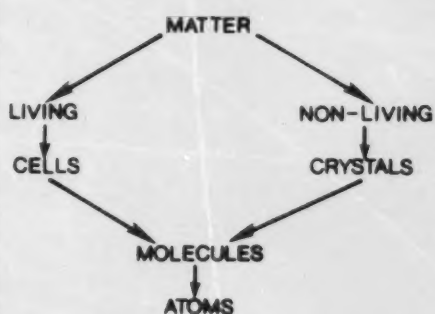
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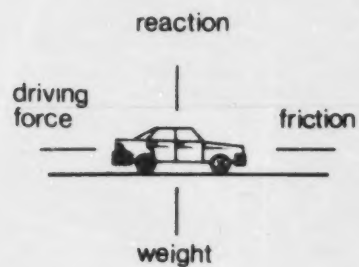
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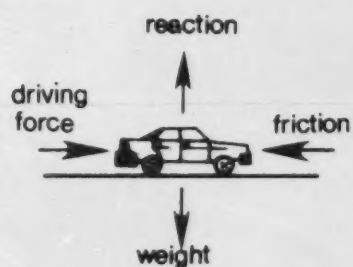
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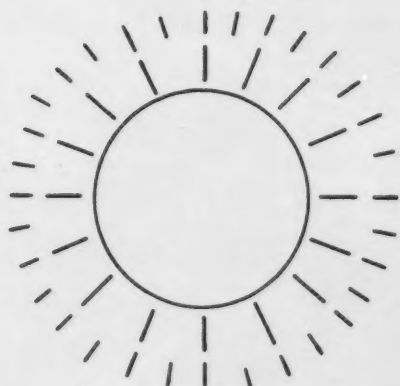
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9



5



10

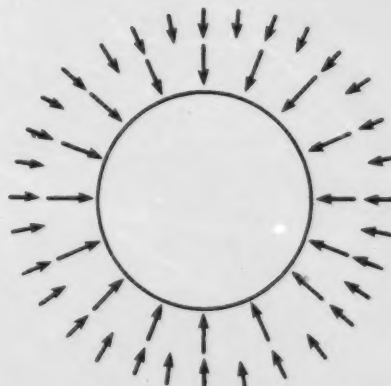


Fig.18-1 The earth's gravitational field

Fig.18-1 The earth's gravitational field

USING SOCIO-COGNITIVE CONFLICT TO ESTABLISH AN UNDERSTANDING OF THE SCIENTIFIC MEANING OF ROCK

John C. Happs

INTRODUCTION

There is a growing body of data which clearly demonstrates that learners, across all age levels, are likely to hold firm, well-integrated beliefs and principles, concerning a variety of natural phenomena.

When workers comment about 'probing prior knowledge' (White, 1982), 'exploring students' views of the world' (Osborne and Gilbert, 1980), 'investigating layman's science' (Shanon, 1976), or 'assessing children's concepts' (Nussbaum and Novak, 1976), they are using different phrases to describe a similar goal, namely that of seeking some understanding of the student's 'conceptual framework'. The term 'conceptual framework' has been defined by Driver (1973) as:

'a set of beliefs or expectations a person has about a system or systems, and constitutes the knowledge he has about the system, in that it is a basis upon which he both perceives it (i.e., it determines the perceptual aspect he pays attention to) and predicts the outcome of actions on that system'. (p.24)

These beliefs or expectations can be difficult to change (Ausubel, 1968) and teaching methods, which attempt to transfer scientific knowledge and understanding into 'empty minds', may be doomed to failure since many learners seem unable to combine formal scientific information with their intuitive notions of the world around them (Papert, 1980). It is likely that these intuitive ideas either prevent the understanding of new incoming information, or else so modify it that it becomes unrecognisable as 'scientifically valid' data, when it is recalled by the learner.

The existence of students' alternative frameworks is well established. Investigations using a range of methods, and undertaken in a number of countries, have shown remarkable similarities in children's views. Publications on children's ideas can be found in most science education journals with collections of such reports appearing in Archenhold *et al.*, 1980 (see also the Australian Science Teachers' Journal, 1981).

The combined efforts of workers who are probing the learner's prior knowledge and learning theorists, such as Novak (1979) and Wittrock (1980), have led to

information about the causes of student conceptions and, more recently, how some of these alternative frameworks might be modified by the use of appropriate teaching strategies (Champagne, et al., 1981; Hewson, 1982).

While many of these investigations into children's ideas have centred on topics from physics, chemistry and biology, studies which focus on topics from the Earth Sciences can now be found. Such investigations have considered children's conceptions of the Earth (Nussbaum and Novak, 1976; Nussbaum, 1979); children's concept of the Earth and Sun (Klein, 1982); student understanding of soil (Happs, 1982c) and how learners classify rocks and minerals (Happs, 1982d).

AN INVESTIGATION OF STUDENT UNDERSTANDING ABOUT ROCKS AND MINERALS

Information has been obtained about the learner's understanding of rocks, minerals and associated terms, by interviewing 34 students in Forms 1 through 7 (3 to 6 from each) from three intermediate and six co-educational secondary schools (Happs, 1982e).

During individual interviews (each lasting 30-45 minutes), students were asked to examine a number of rock and mineral samples, with later questioning eliciting as much information as possible, about the student's views concerning the samples.

Thirteen cards were later shown to each student, and a stimulus-word (e.g., rock, igneous, pumice) was written on each card so that students were provided with a further opportunity to give more information about rocks and minerals. By these means, information was obtained in the following areas:

- (i) ways in which children and adolescents view and describe rock and mineral samples and how they relate these ideas to rock and mineral origins and composition;
- (ii) ways in which learners tend to categorise rocks and minerals;
- (iii) ways in which learners respond to key stimulus-words that are considered, by earth scientists, to be important in the study of rocks and minerals.

SOME FINDINGS FROM THIS INVESTIGATION

Information from this investigation revealed that learners have different ideas and points of view about rocks and minerals. These have been compared with those views held by earth scientists:

(i) the word 'rock' tends to be associated only with the common usage of the word, i.e., a boulder-sized fragment of hard, dense and dark-coloured rock, whereas the earth scientist might define rock as solid, natural material which is made up of minerals;

(ii) terms such as 'crystal', 'stone', and 'pebble' were commonly used by pupils to describe rock and/or mineral samples. The usage tended to be loose and non-scientific. Factors such as physical appearance, shape or the weight of a rock fragment and/or mineral sample being used as criterial attributes, whereas these attributes would be irrelevant to the earth scientist;

(iii) learners rarely associated the word 'mineral' with rock and/or mineral samples, whereas the earth scientist tends to define rock in terms of mineral assemblages;

(iv) unlike earth scientists, most pupils did not consider that rocks can (and should) be classified according to their modes of formation. Rock names tend to be ascribed, by pupils, on the basis of everyday language, e.g., 'ordinary rocks', 'shiny rocks', etc.;

(v) whereas the earth scientist is likely to place size ranges on a number of particle terms such as 'boulder', 'pebble', 'sand', and 'clay', pupils frequently consider features such as physical appearance or the weight of a sample as criterial attributes, when using these terms;

(vi) learners tended to use a 'size-judgement' when using the term 'stone', whereas the earth scientist has no specific meaning for this word and certainly does not give it any size connotation;

(vii) many pupils perceived a difference between the terms 'rock' and 'a rock' with the latter term being adopted as a size criterion. The earth scientist tends not to discriminate between these terms and assumes that 'a rock' implies a 'rock fragment'. Furthermore, the earth scientist regards both terms as implying natural material, comprising mineral aggregates.

A subsequent study involving graduates (science and non-science) training for secondary teaching showed that they held similar patterns of thought and understanding when compared with primary and secondary students. However, this situation may be anticipated in view of the limited opportunities that exist for teaching about rocks and minerals within the current secondary school science curriculum.

CHANGING STUDENTS' THINKING ABOUT ROCK

The view that children have their own ideas about the world and that these ideas are difficult to change is compatible with a constructivist paradigm in learning (Driver, 1983). The works of Piaget, Kelly, and Wittrock also lead to a number of assumptions that might be made if teaching strategies are to be designed with the learner's position in mind. Such assumptions are:

(i) learning is concerned with students modifying or building upon cognitive structures. The development of these structures is affected, in various ways, by different teaching strategies;

(ii) learners will construct meaning through an interaction between his/her prior knowledge and stimuli from the environment;

(iii) stimuli may be in the form of text, verbal information or the observation of phenomena. Such stimuli are rarely interpreted in exactly the way the teacher intends them to be;

(iv) teaching strategies cannot be designed so as to transfer knowledge directly into the learner's mind, rather they need to be designed to place the student in situations which will assist him/her in constructing scientific frameworks.

DESIGNING A SUITABLE TEACHING STRATEGY

Establishing the 'quality' of prior knowledge and then simply offering students counter examples is not likely to lead to a change in pupils' ideas. Driver (1973) showed that conflicting evidence sometimes leads to confusion in the student's mind. She stressed that the presentation of an alternative theory, which better accounts for the data, is often not necessarily understood, but accepted and learned at a verbal level.

Nusbaumb and Novick (1981) regarded this failure to achieve cognitive conflict and conceptual change as being due to the fact that the student's alternative framework is an integral part of cognitive structure and (s)he may not be fully aware of its existence. This failure to recognise such embedded ideas and assumptions prevents the learner from recognising conflict and the necessity for conceptual shift.

Piaget (1932, 1950, 1967) has placed considerable importance on peer interaction in learning, suggesting that such interaction offers the learner experience of contrasting points of view, opinions and explanations that may persuade him/her to justify currently held ideas. Furthermore, Piaget adopted the position that problem-solving, with others, is a necessary condition for the development of individual thought (Silverman and Stone, 1972).

On the basis of these ideas, a teaching 'package' on rocks and minerals has been developed. The aim of this material is to help students construct a scientific meaning for the word 'rock' and associated terms, by means of socio-cognitive conflict situations.

PROBLEMS INVOLVED IN LEARNING

In order to explore issues involved in teaching and learning, using the above approach, a range of probes are being used. These are used to provide measures of cognitive structure both prior to and following instruction as well as offering some measure of retention. Techniques used include word association surveys, interviews and repertory grid analyses. In addition to this 'monitoring' of cognitive structure, classroom observation, and analysis of actual teaching-learning interactions are being undertaken.

Observations and analysis of individual lessons can highlight the complexities in learning and the importance of prior knowledge in this learning process. The following case-study extracts emphasize some problems.

EXTRACTS FROM A CASE STUDY

Joanna, Gordon, Steven, Maree, and Heather were all Form 4 (14 year old) pupils at a co-educational secondary school, having been described by their science teacher as being of 'average scientific ability'. These five students made up one group which interacted with the materials and a worksheet, designed to move their thinking toward a scientific appreciation of the term 'rock'. No instruction had been provided about rock, prior to this encounter.

The opportunity was provided for each pupil to offer his/her initial 'definition' of the word 'rock'. Expressions such as 'hard stone', 'large stone', and 'a solid form of matter' emerged and, from these starting points, students were given 8 objects (small pieces of scoria, greywacke, brick, wood, granite, plastic, glass, and marble) to categorise as 'rock' or 'not rock'.

When disagreement occurred over particular samples the teacher encouraged students to resolve any differences of opinion through group discussion. Following such discussion, the earth scientist's classification was revealed and discussed. Pupils then attempted to induce the 'scientific' definition which was subsequently presented to them.

Following this procedure, 10 other samples were provided (small pieces of ignimbrite, serpentinite, granite, marble, limestone, pottery fragment, slate, tufa, sea-shell, and sandstone). Pupils were asked to discuss these and categorise them according to the 'scientific' definition.

SOME WAYS IN WHICH THE LEARNER'S INTERPRETATION OF KEY WORDS,
WITHIN A DEFINITION, CAN INFLUENCE THE CONCLUSION REACHED

Example 1: The teacher has provided a definition of 'rock' which includes the words 'solid, natural material'. In the teacher's meaning of the word, 'solid' implies cohesive material which is not a liquid or a gas, yet this meaning is not apparent to Heather, Steven and Maree, as the following conversation extract shows:

- T. 'What about those people who thought it was not rock?'
- H. 'It crushes too easily - rock usually, umm, but it's quite hard and it takes a lot to crush it and that (points to scoria) looks as if it's going to fall apart if you put a lot of pressure on it'.
- S. 'There are different sorts of rock. It (scoria) looks soft - I'm not sure'.
- T. 'Is that important - hardness or softness?'
- S. 'Rocks are usually - sort of - pretty solid things'.

<u>INFORMATION PROVIDED</u>	<u>TEACHER'S ASSUMPTION</u>	<u>CONCLUSION SOUGHT</u>
rock is <u>solid</u> , natural material, found on or below the surface of the Earth.	→ sandstone is seen to be solid, i.e. co- hesive particles, not liquid or gas.	→ sandstone is solid natural material and must be rock.
<u>TEACHER'S INTENTION</u>		
<u>INFORMATION OBTAINED</u>	<u>LEARNER'S INTERPRETATION</u>	<u>CONCLUSION REACHED</u>
rock is <u>solid</u> , natural material, found on or below the surface of the Earth.	→ <u>solid</u> means hard, i.e. difficult to break.	→ Sandstone breaks easily and so cannot be called rock.
<u>PUPIL'S RESPONSE</u>		

Example 2: From the same definition of 'rock', we see how Heather places an idiosyncratic meaning on the word 'natural':

- H. 'No'. (rejecting the marble as rock)
- T. 'Tell me about that - why not Heather?'
- H. 'It's not a natural rock anyway because it's been sanded down and someone has gone along and sanded it down so it's smooth and not natural'.
- J. 'Yes, but it was still dug out of the ground'.
- H. 'They've put a hardner on top of it so it won't lose its flat surface'.
- T. 'What if these people are right (teacher points to others in the group) - it was natural material and man has just smoothed it down?'

- H. 'Then they've put something on top of it so the rock won't wear away'.
 G. 'But in the beginning it was still natural'.
 H. 'Everything is natural until man touches it'.

The interpretation of the word 'natural' controls the conclusion reached by this student:

<u>INFORMATION PROVIDED</u>	<u>TEACHER'S ASSUMPTION</u>	<u>CONCLUSION SOUGHT</u>
rock is solid, <u>natural</u> material, found on or below the surface of the Earth.	→ the sample of tufa will be seen to be solid and natural.	→ the sample will be identified as rock.
<u>TEACHER'S INTENTION</u>		
<u>INFORMATION OBTAINED</u>	<u>LEARNER'S INTERPRETATION</u>	<u>CONCLUSION REACHED</u>
rock is solid, <u>natural</u> material found on or below the surface of the Earth.	→ <u>natural</u> implies no influence by man, i.e. completely natural and untouched.	→ face of sample obviously cut and polished. Sample cannot be rock.
<u>PUPIL'S RESPONSE</u>		

Despite arguments to the contrary from one of her peers, Heather still resists the alternative explanation. This is shown in the following condensed extract:

- H. 'No - it's been polished'.
 T. 'It's for the same reasons as the other one there?' (points to sample of granite).
 H. 'Yes'.
 T. (turns to others) 'Are you going to convince Heather - or is Heather going to convince you?'
 G. 'No, I reckon that in the beginning they all started off as one form of rock and somebody's just dug them out and just sanded it off. It's only the outer surface, it's still ...'
 S. 'They've just sanded it down'.
 G. 'The whole thing is still rock'.
 H. 'It looks artificial - it doesn't look natural - they've put chemicals on to make it shine'.
 G. 'On the rock'. (laughs)
 H. 'It's got chemicals and everything on it'.
 T. 'So Heather, you think that as soon as man adds something to it, it's no longer rock?'
 H. 'Well, it's not a rock, as like that (points to ignimbrite fragment)'.

SOME WAYS IN WHICH THE LEARNER'S PRIOR KNOWLEDGE CAN INFLUENCE
THE CONCLUSION REACHED FROM OBSERVATION OF CRITICAL PHENOMENA

Example 3: The teacher assumes that the student will focus on the holes in scoria (igneous rock) and then conclude that the rock is formed via cooling lava, from which gases have escaped. However, in the following instance, interview data indicates that the learner does focus attention on holes, but utilises knowledge which was present before instruction in this topic. This prior knowledge proved inappropriate for the classification of this particular rock and the outcome is summarised:

<u>OBSERVATION REQUIRED</u>	<u>PRIOR KNOWLEDGE NEEDED</u>	<u>CONCLUSION SOUGHT</u>
the scoria sample contains holes within its rough surface.	cooling lava may trap and release gas - leaving holes behind.	rock is formed from congealed lava. It is scoria, an igneous rock.
<u>TEACHER'S INTENTION</u>		
<u>OBSERVATION MADE</u>	<u>PRIOR KNOWLEDGE USED</u>	<u>CONCLUSION REACHED</u>
the sample contains holes within its rough surface.	(i) rocks that have been in the sea have holes worn in them. (ii) sedimentary rocks come from the sea.	the sample is a sedimentary rock.
<u>PUPIL'S RESPONSE</u>		

Example 4: The teacher provides a rock fragment which has part of its surface broken, suggesting some sort of cleavage plane. Although the rock is not sedimentary the presence of a flat face is interpreted as being layering, by the student. Consequently an incorrect observation and inappropriate prior knowledge leads to the wrong conclusion:

<u>OBSERVATION REQUIRED</u>	<u>PRIOR KNOWLEDGE NEEDED</u>	<u>CONCLUSION SOUGHT</u>
the sample is not made up of individual particles.	sedimentary rock is made up of particles → 'cemented' together.	the sample is not sedimentary → rock.
<u>TEACHER'S INTENTION</u>		
<u>OBSERVATION MADE</u>	<u>PRIOR KNOWLEDGE USED</u>	<u>CONCLUSION REACHED</u>
sample has a clean break which looks like layering.	sedimentary rocks → are often found in layers.	sample is a → sedimentary rock because it has layering.
<u>PUPIL'S RESPONSE</u>		

CONCLUDING COMMENT

Socio-cognitive conflict situations, along the lines discussed in this paper, have been used throughout a prototype 9 x 1 hour teaching program dealing with rocks and minerals. Whilst this study is continuing, analysis of teaching-learning situations to date have highlighted the problems, and importance of prior knowledge, and how, only through an emphasis on exemplars and non-exemplars, can the interpretations of definitions be clarified.

It is hoped that further trialling and development of this technique, within the context of the topic 'rocks and minerals', will lead to the production of a teaching strategy which might prove of use to practitioners who seek an alternative approach to teaching in this area.

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CHILDREN'S EXPLANATION OF NATURAL PHENOMENA

David J. Symington and Richard T. White

INTRODUCTION

The subject matter of science can be divided into knowledge of phenomena and the explanations of them. Some studies investigate the extent or nature of people's knowledge (e.g., Champagne, Klopfer, DeSena, & Squires, 1981) and others the form of explanations they give (e.g., Osborne, 1980; Rodrigues, 1980). While both sorts of study are useful, the latter appears more penetrating, revealing more of the processes by which people make sense of the world. This may be because explanations are less commonly taught directly than knowledge, and because they are more subjective and debatable.

Many recent studies show that scientists often explain natural phenomena differently from laymen (Helm, 1980; Viennot, 1979; Osborne, 1980; Gunstone & White, 1981). This difference is a matter of concern, particularly since it has been found to persist despite instruction. Determined efforts to bring secondary school students' conceptions into line with scientists' have run into difficulties (Gunstone, Champagne, & Klopfer, 1981), which suggests that we need to know more about the ways people form their conceptions. We would then be better able to design instruction that would change conceptions. This study was planned as a first step towards that aim. Its genesis was discussions the authors had with members of the Learning in Science Project (Primary) at the University of Waikato.

The present study consists of observations of the explanations offered by sixth grade children, with the general purpose of seeing how they are acquired and retained. We wanted to see whether the explanations could be categorised, and if they could, which categories were retained best. We also wanted to identify salient issues in the teaching of explanations. Among these were the influence other students' ideas had on the explanations each learner adopted or kept; the reasons why a learner rejected some explanations; and the relation between classroom events and the explanations which are retained.

PROCEDURE

In order to investigate the development, acquisition, and retention of explanations we needed a suitable phenomenon and a general plan.

Symington, Osborne, Freyberg, and White (1982) have argued that the phenomena need to be 'part of the child's immediate world and ... about which the child is interested' (p.6). Many topics fit this requirement, so the choice of bark on trees was rather arbitrary. If that had not turned out to interest the children, we would have tried something else.

The general plan is shown in Figure 1.

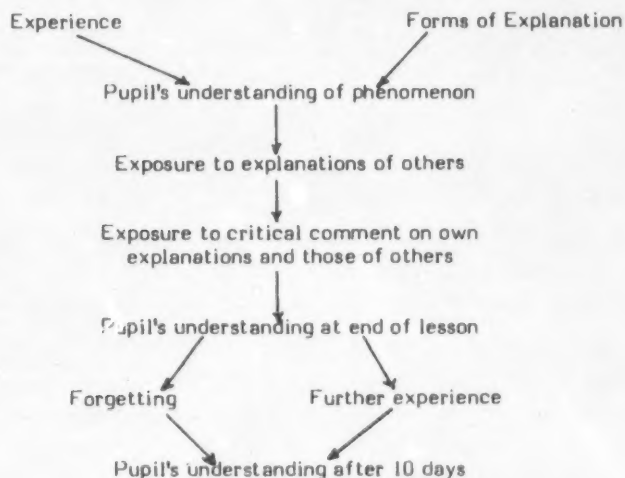


FIGURE 1
Model underlying the investigation

We considered that the children would bring to a classroom discussion of the topic episodic recollections of their experiences with bark and the forms of explanation they had acquired, more or less incidentally, from interactions with adults and their peers. At the commencement of the investigation we did not know what these forms might be. After obtaining from children their initial explanations of the phenomenon, we planned on having them hear the explanations of their classmates and the criticisms that members of the class made of each other's

explanations, before determining again their views. We then would allow some days to pass, during which loosely held explanations might be forgotten or further experience, sensitized by the discussion of the topic, might bring them to add or reject deliberately an explanation.

In accord with this plan, the two main phases of the investigation were a class lesson to record, collect, and discuss explanations proffered in response to a question about bark, and then 9 or 10 days later individual interviews to see which explanations the students adhered to. The investigation involved two sixth grade classes in the same school. The lessons and the interviews were carried out by the first author.

The class lesson. The students were asked what they would like to know about bark on trees, and from their responses the investigator chose the following for discussion: Class 1, Why does the tree need bark? And Class 2, Why is bark there? The students were asked to write as many answers as they could think of to the question.

Their answers were listed on the board, and were discussed by the class; the investigator acted as chairman, and did not contribute any ideas of his own to the debate until the summing up, when he pointed out some answers reflected a tree-centred view and others a nature-centred view, and in Class 2 that there were also some human-centred answers (see Table 1). In Class 1, but not Class 2 because of lack of time, at the end of the lesson the students were asked to write down which answers they now thought should be rubbed out from the class list, and to give reasons why.

The interviews. The students were interviewed individually 9 or 10 days after the class lesson. The interviews were recorded.

Different procedures were followed in the two classes. The students from Class 1 were asked what they now thought about why trees have bark. They were then shown the list of answers given by their class and asked which ones were not good answers; if they did select any, they were asked for their reasons. Finally they were asked if they could group the answers in any way.

With Class 2 the first question was the same, but then the students were asked to recall and evaluate the suggestions that other students had made in the lesson. They were asked to explain any difference between their present views about why trees have bark and what they had written at the beginning of the class lesson. Finally they were asked to comment on the teaching strategy used in the lesson.

TABLE 1
Questions and Answers Obtained in Class Lessons

Questions asked about bark	
<u>Class 1</u>	<u>Class 2</u>
How does bark form?	*Why is bark there?
What does the fungus grow on it for?	What does bark do?
How come there are so many insects under the bark?	How did bark get its colour?
*Why does the tree need bark?	How does it get there?
Does bark have any sap going through it?	What is it made of?
(*Questions selected for discussion)	
Total set of written answers to selected question	
To protect the tree from insects.	To protect the tree from sunshine, dogs, fire, disease, animals.
To protect the tree from dirt.	To protect the tree from enemies.
To protect the tree from possums.	To protect the inner layers of the tree.
To protect the tree from sunshine.	To stop the sap from coming out.
To protect the tree from fire.	For its beauty.
To protect the tree from animals.	To take in dirty air and put out fresh air.
To protect the tree from the cold.	To hold food that the tree needs to grow.
To protect the tree from the wet.	To add some colour to the tree.
To keep it warm.	To help cats sharpen their claws.
So insects can live there and build their nests.	For making paper to write and draw on.
It could have something to do with the sap.	It is the skin of the tree.
To feed it water.	To make the tree look more interesting.
To keep it from drying up in the sun.	It tells how old the tree is.
To keep the inside alive.	To help animals climb the tree.
To keep the sap inside the tree.	To make homes for insects and spiders.
To keep insects alive.	To help obtain food.
To keep the tree alive.	
So the tree doesn't get eaten.	
For its growth.	

RESULTS

The lessons and interviews produced several sets of data:

- (i) class lists of questions about bark which the students wanted answered;
- (ii) individual written lists of suggested answers to the questions Why does the tree need bark? (Class 1) and Why is bark there? (Class 2);
- (iii) individual lists of answers which the student thought should be rubbed out, and the reasons (Class 1 only);
- (iv) recordings of individual interviews.

Table 1 contains the class lists of questions and the total set of written answers for the two classes.

The main interest in the interviews was to see what changes the class discussion and the intervening 9 or 10 days had produced.

ANALYSIS OF THE DATA

The purposes of the study were to see whether the explanations students offer for a phenomenon could be categorized, to see what types of changes in explanations occurred, and to seek connections between classroom events and the changes which occurred.

Types of explanations. The students' explanations suggested two forms of categorization, one to do with the centre of purpose and one with the form of logic.

Compared with the other questioning words 'how', 'what', and 'when', the word 'why' implies a purpose. The students' answers are readily classed according to which object's purpose they relate to. At first we found some of the explanations odd, because we are acculturated to the view that scientific explanations are in terms of natural, purposeless propositions or in terms of motives for animals only. Thus we respond to questions such as 'why is there a rainbow?' with descriptions of light paths, refraction and reflection, or to others such as 'why did the Church oppose Galileo's teaching?' with statements about the advantages its leaders saw in doing so. The sixth grade children, however, have much wider notions of purpose. Some of their answers are in terms of the tree's purpose, such as to protect it, keep it from drying out. These are close to the scientific view that has prevailed at least since the principles of natural selection were accepted. Others relate to a human purpose: for its beauty, to make the tree look more interesting, to tell how old the tree is, and for wood to make things. A third centre of purpose is animals: to help cats sharpen their claws, to help animals climb the tree, and to make homes for insects and spiders.

The logic classes run across the centre-of-purpose ones. They are analogy, cause and effect, and generalization.

Tien used the analogy of skin in his explanation. 'Bark is there because it is the skin of the tree - I think. Every season the old skin rips apart and another skin comes out'. Yvonne's thinking about trees was also influenced by analogy. She argued that bark was needed to keep the trees warm. 'Because you have to keep them warm in winter when it really gets cold'.

In many explanations causal thinking can be seen. The child puts together several observations and assumes a causal relationship. For instance, Sandra concludes that without the bark, the fungi growing on the outside of the bark would kill the tree. A great number of the explanations proposed appear to be based upon the generalization that 'living things need protection'. It is interesting to note that many of the students had to be prompted during the interview to amplify on their explanation that bark is there to protect the tree.

Forms of change in explanations. The explanations a child offered initially could change through the class discussion and during the interval between the lesson and the interview. At least six forms of change are possible.

- 1 New explanations are added.
- 2 Initial explanations are deleted.
- 3 The centre of purpose changes.
- 4 Views of others are appreciated without being accepted.
- 5 The student's own view is amplified without changing in nature.
- 6 The student's confidence in his or her own view changes.

Instances of the first four of these forms of change can be found in the data. The method of data collection did not facilitate collection of evidence of the latter two forms of change. Quite a few pupils provided more elaborate explanations after the experience but this could be due to the fact that these were oral whereas the initial explanation was written.

In Class 2 a number of children (Jamie, Tien, and Rochelle) added explanations. For example, Rochelle recalled that other children had suggested that bark was there to protect the tree and she had added this idea to her own repertoire.

By the time of the interview some students in Class 2 (Sandra, Cathie, Mark, Chris, Ross, Louise, and Christine) had deleted explanations. Several indicated that it was the class discussion that led them to change their minds. Mark, for instance, indicated that he rejected his earlier idea that the bark was to stop the sap from

coming out when one of the class members said that the sap comes from the middle of the tree: 'So the bark couldn't be there to keep the sap in'. For others rejection came later from thought and action stimulated by the class discussion. Initially Louise included in her reasons for trees having bark the case that 'it is there to make the tree nice'. Later she deleted this idea from her explanation because she thought about it while gardening and decided that bark doesn't always look attractive.

Chris and Christine exhibit a change in the centre of purpose. They dropped explanations where the tree was providing a service to something other than itself. Christine was convinced by the discussion that although cats do sharpen their claws on the bark, the bark was not there for that purpose.

The children in Class 2 were asked in the interview whether they could recall other children's explanations. Their responses show that they could both recall and evaluate them. Some were accepted as reasonable without becoming part of the child's own explanation. For example, Nicole remembered the suggestion that bark could protect the tree from fire and accepted it as a valid possibility but had not incorporated the idea into her own thinking about why trees have bark.

Extent to which children changed their explanations. Despite the fact that individual instances of change can be cited, the overwhelming impression is of the lack of change. The Class 1 children show a remarkable consistency between their initial written reasons and those they gave in the interview 9 days later. The data show that those interviewed added no explanations, or deleted any, despite the class discussion in which they saw other children's explanations written on the board and heard much talk about them. The children in Class 2 showed some alterations, which have been cited earlier; however, they are not numerous. The explanation for the absence of change cannot be lack of involvement in the lesson. The interview data revealed both an enthusiasm for the method adopted and evidence that most children could remember ideas that had been verbalized during the lesson. Almost all of the pupils could remember some of the answers that others had given to the question of why trees have bark.

Reasons for rejecting the explanations of others. Many of the explanations recalled were rejected, generally for sophisticated and rational reasons. Most rejections fall into one of three types: rejecting the factual basis of the explanation, rejecting the assumptions behind the explanations, and identifying contradictions within explanations.

There are plenty of instances of rejection of the factual basis. Nicole rejects the reason that bark is there to stop the sap coming out because sap does come out, and Cathie because the sap does not run next to the bark but inside the tree. Ross (who exhibits some inconsistency with his own response) rejects the reason that bark protects the tree from heat because bark burns easily; and Louise rejects protection from disease because of her own observation of a diseased tree.

Examples of rejected assumptions are provided by Jamie (2), who says bark is not there to keep trees warm because trees cannot feel the cold, and Jamie (1), who says bark is not there to store food because roots do that. Other examples came up in the discussion part of the lesson: bark is not there to keep insects alive because 'as soon as the insects get inside the bark they are going to gnaw at the tree so what's the purpose of keeping insects alive in the tree?' Perhaps the most sophisticated answer, one that exhibits a level of logic and knowledge that few would expect from a sixth grade child, is that of Voula, who rejects the notion that bark is there to protect the trees from animals because 'when the trees were first created there were no animals around'.

The class discussion revealed that some pupils saw a contradiction between 'Bark is there so the tree doesn't get eaten' and 'Bark is there so insects can stay alive'; the argument was advanced 'How can insects stay alive and not eat the inside of the tree?'

DISCUSSION

The data provide instances of categories of explanation and instances of four of the six forms of change in explanation proposed by the authors.

The study has also provided examples of factors that cause children to change their views: some accepted explanations put forward by others; some rejected part of their own thinking when they believed the class discussion had demonstrated flaws in their argument; and some had thought more about the topic and changed their minds at some time after the lesson (the lesson having acted as an initial stimulus). Further, the study revealed three forms of reasoning used to reject explanations offered by others.

However, the number of children whose views were changed by the experience was small. We therefore are unable to identify whether some types of explanation are better retained than others. More importantly, we are left with the tantalising question of why so little change occurred. Perhaps once many of these children had created their own explanation by writing a response to the question 'Why do trees have bark?', that was sufficient for them. Reasons given subsequently by others were

listened to but not absorbed, perhaps because the students did not need them once they had their own set. The parallels of this observation with those of Gunstone, Champagne, and Klopfer (1981) are close: in their attempt to shift children from an Aristotlean to a Newtonian view of the world they obtained superficial agreement with the new principles but were unable to eradicate the original view, which was held tenaciously. This phenomenon, of the stability of an explanation once formed, is the most puzzling to emerge from this study. As it lies at the heart of teaching, we need to investigate it more deeply.

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READING AND THE LEARNER OF SCIENCE

Beverley Bell

Science students, especially at the secondary and tertiary levels, are at times required to learn by reading scientific texts. This is particularly so on occasions when the teacher is not present in the classroom - for example, due to illness, or attendance at an inservice course, or when homework is being done (Bell, 1982a). At other times, textbooks may be used to supplement the teacher's classroom input.

THEORETICAL PERSPECTIVES ON LEARNING

The role of existing knowledge (also called prior knowledge) has been promoted in reading comprehension research by the schema theorists (Anderson 1977; Pearson & Spiro 1982; Rumelhart 1980; Rumelhart & Ortony 1977; Schank & Abelson 1977; Spiro 1980b). It is widely accepted that a person's existing knowledge also plays a critical role in the learning of science. The many studies describing the influence of a learner's existing knowledge are documented in Driver (1982) and Osborne and Wittrock (1982).

Learning may be viewed as an active, constructive process of the learner (Ausubel 1968; Kelly 1971; Wittrock 1974). With respect to reading, Spiro (1980a) argues that meaning does not reside in the words, sentences or paragraphs on a page but that it is constructed in the reader's head. This constructed meaning results from the interaction of the text and the context, which Spiro takes to include prior knowledge and linguistic, situational, attitudinal and task contexts. The reader must expend effort to comprehend the print, i.e., the reader in comprehending a text is active, not passive. Wittrock (1981) likewise considers reading comprehension as a process in which the meaning must be generated by the reader. In generating a meaning, the reader is constructing a representation or explanation of what is decoded, and is organising this incoming information in a way that makes sense to her or himself. The generative learning model (Osborne & Wittrock, in press) hypothesises key elements of the learning process through which learners construct meaning. These key elements are:

- 1 The existing knowledge of the learner is viewed as the beginning point for the construction of meaning from any experience, not the experience itself. Existing knowledge influences what will be selected and attended to in the environment.
- 2 The sensory input selected and attended to by the learner, of itself, has no meaning.

- 3 In the construction of meaning from sensory input, links are generated by the learner between the stimuli attended to, and what is perceived as relevant existing knowledge. The links are central to and important determinants of the constructed meaning.
- 4 The initial or tentative construction is evaluated against the existing knowledge and against the sensory input. This evaluation may result in a restructuring of the existing knowledge. That is, learning may occur.
- 5 The learner is active in constructing a meaning in terms of attending to selected stimuli, generating links to existing knowledge and evaluating the construction.

Similar ideas on learning are embodied in the model of conceptual change proposed by Hewson (1981a,b, 1982). He states that when a learner encounters a new conception, the new conception can be (1) rejected or (2) incorporated in three possible ways. It could

- (a) be memorised by rote (i.e., not necessarily reconciled with existing conceptions);
- (b) replace an existing conception and be reconciled with the remaining conceptions by the process of 'conceptual exchange'; or
- (c) be reconciled with existing conceptions by the process 'conceptual capture'.

What in fact does happen to a new conception, depends on whether it is seen as:

- (a) intelligible (I) in that it appears coherent and internally consistent;
- (b) plausible (P) in that it is reconcilable with other aspects of the child's view of the world, or
- (c) fruitful (F) in that it is preferable to the old conception on the grounds of perceived elegance, parsimony and economy.

Therefore, a conception can have

- (a) no status (not intelligible, plausible or fruitful)
- (b) status I (intelligible but not plausible or fruitful)
- (c) status IP (intelligible, and plausible but not fruitful)
- (d) status IPF (intelligible, plausible and fruitful).

The dynamic aspect of the model is that the status of a conception changes during learning. Hence, like the generative learning model, Hewson's model of conceptual change takes into account the constructive nature of learning, the role of existing knowledge, and the evaluation of a construction.

In summary, learning through reading may be viewed as an active, constructive process in which the existing knowledge of the reader/learner plays a critical role. This paper reports the findings of research which investigated the interaction of the reader/learner's existing knowledge and text during reading to learn.

THE RESEARCH

Earlier research (Bell, 1981) illustrated that many secondary students do not have a scientific meaning of the word animal, having instead, as part of their existing knowledge, an everyday meaning. In the everyday meaning of animal, only the large, furry fourlegged terrestrial mammals - for example, a cow and tiger - are considered to be animals. Small creatures - for example, a spider and worm - people, and the marine animals - for example, a dolphin, fish and shark - may not be considered animals. The everyday meaning is a restricted or narrower meaning, with respect to exemplars, than the scientific one.

The distinguishing features of an animal, in the everyday sense, are mainly related to size, number of legs, and habitat. In the scientific sense, the distinguishing features are mainly heterotrophic feeding and movement.

Early work (Bell, 1982b) suggested that students, who have only an everyday meaning of animal, do tend to use this existing knowledge in comprehending a text on the scientific concept of animal. In this present study, the research questions were:

When students, who have an everyday meaning of the word animal, are asked to read an expository text to learn the scientific concept of animal,

- (a) what meanings do they construct from the text, and
- (b) what is the nature of the reading comprehension and learning process?

Sample

Seven students (aged approximately 13 years) from each of three Form 3 science classes had a different teacher. With the aim of obtaining a sample of average ability children, two tests - Test of Scholastic Abilities (NZCER) and Progressive Achievement Tests (NZCER) - were administered to the three classes. The main part of the sample consisted of students with average scores in the TOSCA and PAT tests, and this was supplemented with students with above or below average scores. The students in the sample were also categorised, on the basis of their responses on science survey on the concept of animal, into one of three groups: those having, with respect to the concept of animal an everyday meaning, a scientific meaning, or an in-between meaning. Students in the first group categorised only the cow as an animal; students in the second group categorised all the instances (cow, whale, person, spider, butterfly and worm) as animals as would a scientist; and students in the third group categorised between two and five of the instances as animals. There were 10 girls and 11 boys in the sample. Further details are given in Table 1.

TABLE 1

The Sample

Score on PAT: comprehension	Classification based on the categorisation of instances as an animal or not, in the initial science survey		
	Everyday meaning of animal.	In-between meaning.	Scientific meaning of animal
Above average	311	313 320 326	321
Average (Level score of 7,8)	319 323 324	307,308,309 316,317,318 322,327,328 329	325
Below average	310	312	

Student code numbers:

Class 1 : Typical text	307 - 313
Class 2 : Text 1	316 - 322
Class 3 : Text 2	323 - 329

Methodology

Having agreed to take part, each student was interviewed twice in a small room in a normal-timetabled science lesson. The interviews were audiotaped with the consent of the student. The first interview of 5-10 minutes (the existing or prior knowledge interview) elicited from the students their reasons for their choice of answers in the science survey. In the second interview of 30-50 minutes, (the reading-to-learn interview), the students were asked to read the text and to:

- (a) learn how a scientist would answer the question 'What is an animal?';
- (b) stop at the end of each sentence and to tell the researcher what they were thinking.

Throughout the interview, the researcher asked probe questions to clarify statements made or implied by the reader. Such questions were: 'What do you understand by that sentence?', 'What are you thinking about now?', 'Does the sentence make sense to you?', 'Do you agree with that sentence?'.

When the student had finished reading the text, she or he was asked if there was anything that was difficult, easy or new in the reading. Then the students were given an informal interview-about-instances. They were asked if each of the following instances was an animal or not, and the reasons for their answer: horse, a marine animal (either whale or dolphin), a person, small animal (e.g., mosquito, weta, snail, slug, or worm) and sometimes the less well known ones of sponges, mussels. This part of the interview was to assess if any learning had occurred during the reading-to-learn interview. The interview recordings were transcribed for further analysis. Finally, after a period of 2-4 weeks, all three science classes were given a parallel science survey to ascertain any change in the concepts of an animal, held by the sample students, in particular.

Texts

Three different expository texts were used, one with students from each class. All three contained factual scientific information answering the question 'What is an animal?'. The main characteristics of each text were:

- (1) A typical text (812 words) was constructed primarily from sentences in published text books currently used in secondary schools. Alterations and additions were made to increase cohesion of ideas and ease of reading. It was characteristic of scientific texts in that the writing style was concise, non-redundant and with few elaborations or examples. The examples of animals given were predominantly everyday exemplars.
- (2) Text 1 (771 words) was written by the researcher and based on the research on children's concepts of animal (Bell, 1981). The text contained specific exemplars and distinguishing characteristics of the scientific concept of animal in such a way as to challenge the everyday concept held by the students.
- (3) Text 2 (774 words) was written by the researcher, and based on the same research findings (Bell, 1981). The text explicitly distinguished between the everyday and scientific meanings of the word 'animal'.

ANALYSIS OF THE DATA

The interview transcripts were analysed with respect to the theoretical perspective of generating and evaluating a construction. This two-step process of learning through reading was in fact supported by the data. Firstly, the reader/learner was required to generate a construction of the text; and secondly the reader/learner was required to make a decision about the status of her or his construction.

1. Making a construction

To make a construction from the text, the students had to generate links between the text statements and what they perceived as relevant existing knowledge. The nature of the links - in particular, what existing knowledge was linked - determined the construction made. This construction may be compared to that intended by the author, and as a result categorised into one of 14 groups. These 14 possible categories are empirically based and are documented in Table 2. The students' constructions, when compared to the author's intended construction, may be regarded as similar (categories a,b,c); irrelevant (d); not acceptable (e) or not made at all (f). Examples of constructions from three of the 14 categories are:

Construction category a, part 3 (a3). Student (309) in the prior knowledge interview was unsure if a human is an animal or not. On reading the first sentence she immediately resolved her uncertainty by constructing the author's intended meaning and rule.

The world of living things can be divided into two main groups: animals and plants.

"All living things can be divided into two main groups: animals and plants" Suppose a human's an animal then - you can't really call a human a plant, so, if the world is divided up into living things, and humans are a living thing, you can't really call a human a plant, must be an animal. (Have you thought about that before?)
Not really.' (309/39a.1,2)

Construction e3. Student (308) made a construction which was not the author's intended one, when she used an alternative meaning of the word 'make'. (She also used an everyday meaning of the word 'animal', i.e., people are not animals.)

Plants can make their own food using the sun's energy but animals are unable to make their own food.

'Well, animals don't have hands and things that they can make their own food with, because they've just got four legs. That's very awkward. They aren't able to do things like we are because we have fingers and hands to help us. (So people can make their own food?) Yeah - they could grow their own crops, they could buy things or like grow things to make things - biscuits and that'.
(308/39b.2)

TABLE 2
Construction Categories

LINKS TO EXISTING KNOWLEDGE	TENTATIVE CONSTRUCTION
a. The links made by the reader are supported by the author's intention.	The reader's construction is as the author intended, and 1. The text information is not elaborated on by the reader who simply rephrases the text statements in her or his own words. 2. The reader adds relevant existing knowledge to the discussion of the construction. 3. The reader's construction indicates the use by the reader of a rule or generalisation. 4. The reader constructs the author's intended meaning by linking two separate pieces of text information.
b. The links made by the reader are supported by the author's intention but the existing knowledge used is restricted.	The reader's constructed meaning is partially acceptable only, as the construction is restricted or less extensive than the author's intended construction, and 1. The text information is not elaborated on by the reader who simply rephrases the text statements in her or his own words. 2. The reader adds relevant existing knowledge to the discussion of the construction. 3. The reader's construction indicates the use of a restricted rule of generalisation.
c. The reader's links are supported by the author's intention but the existing knowledge used is over-generalised.	The reader's construction is acceptable in part only to the author, as the construction is over-generalised.
d. The reader's links are supported by the author, but the existing knowledge used is considered by the author as irrelevant to the main ideas in the text.	The reader's construction is acceptable to the author, but it is semi-irrelevant.
e. The reader's links are not supported by the author as the existing knowledge used is unacceptable.	The reader's constructed meaning is not as the author intended because of the meaning used by the reader for: 1. key concept words, e.g. living 2. other scientific words 3. common words 4. other symbols
f. No links are made by the reader between the text statements and her or his existing knowledge.	The reader fails to generate a construction.

Construction f. In this example, student (324) could make no link between the text statement and his prior knowledge.

An example of when we use the word animal in the everyday sense is when we go shopping.

'... don't know how they get shopping out of that first one there ... when we use the word animal in an everyday sense is when we go shopping - How [do] they get an animal into an everyday sense with shopping?'
(324/46a.5)

2. Making a decision about the status of the construction

The second activity undertaken by the student involved an implicit or explicit decision about the status of his or her construction. The learner either accepted or rejected the construction, or was unable to make a decision. In all three instances, the decision would have to be made (or attempted) by comparing the construction with the reader's existing knowledge. Hence, the decisions about the status of the constructions can be categorised into three empirically based broad groups (see Table 3).

Examples of three status quotations from the reading-to-learn interview transcripts are:

Status category X, part 1 (X1). Student (308) indicated acceptance of her construction by validating the construction with her prior experiences

All caterpillars found in your garden are herbivores and all have mouth parts for biting and chewing plants.

'Caterpillars, I've often seen caterpillars chew their way round leaves'. (308/39b.5)

Status Y1. Student (318) was unsure to accept or reject the construction as he was unable to recall from his prior experiences the number of legs that spiders and wetas have.

Spiders are animals with eight legs.
A weta is an animal with six legs.

'I'm not quite sure if they have 8 or 6 - I haven't really studied a spider. I've studied a weta and if I did, well, then I'd know if it had 6 or 8, but I'm not quite sure.'

TABLE 3

Status Categories

- X The reader accepts the construction.
 - O No specific information is given by the reader.
Acceptance is inferred by the researcher.
 - 1 The reader knew of the information already. The construction matches the reader's existing knowledge.
 - 2 The reader accepts the construction over her or his existing knowledge. Higher status is given to the new information.
 - 3 The reader accepts the construction because any construction made from print must be right.
- Y The reader is unsure as to whether to accept or reject the construction because:
 - 1 The reader is unsure about the validity of her or his existing knowledge when compared to the construction made from the text.
 - 2 The reader is unsure about the validity of the construction made from the text, when compared to her or his existing knowledge.
 - 3 The reader is unsure about both the existing knowledge and the construction - neither is given more validity than the other.
- Z The reader dismisses or rejects the construction because:
 - 1 of conflict with existing knowledge, which can be made explicit;
 - 2 of conflict with tacit existing knowledge;
 - 3 a more plausible and intelligible alternative construction is generated.

A cow is an animal with four legs.

'A cow is an animal with four legs, yes, because there's sort of see a cow every day, not every day but it's something much bigger than a spider so you'd sort of see it more'. (318/47a.5)

Status Z1. Student (310) rejected the construction criterion of feeding.

Some living things are put into the group of animals because of the way they feed.

'Doesn't mean anything really, because I don't think it's right - because you don't judge things [on] the way they feed, what they are. (What sort of things would you look at instead?) I don't know.' (310/40b.1)

FURTHER CONSIDERATIONS

The above model has been useful as a framework for analysing individual learning interviews. An analysis of the interview transcripts showed that to learn through reading, the students had to construct and to accept the scientific meaning of the word animal. However, further consideration of the transcripts suggests that learning the concept of animal does not involve making and accepting a single construction, but several, namely:

- 1 that living things can be divided into two groups: animals and plants;
- 2 the set and sub-set relationship between the group of animals and the different animal groups;
- 3 the rule of heterotrophic feeding, and what the different animals feed on;
- 4 the different animal exemplars.

While some students in the sample did construct and accept the author's intended meaning for all four points, most did so for only some of them. Failure to learn the scientific concept may have occurred at either the construction or status stage for some of the above four points.

FURTHER RESEARCH

Students' success or failure to construct and to accept the scientific meaning of animal with respect to the different texts is being investigated further. A more controlled reading situation is being explored, with systematic variation of the same content material in different contexts, in an attempt to verify experimentally the hypotheses derived from the observations described above.

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INVESTIGATION OF STUDENTS' UNDERSTANDING OF SPEED, VELOCITY AND ACCELERATION

Alister T. Jones

INTRODUCTION

A student will often bring concepts to the classroom which are different from those of the teacher (Gilbert, Osborne, & Fensham, 1982). Identification of these concepts means that educators can address themselves to problems as they actually are, rather than they are imagined to be. A number of studies have been undertaken to describe some of the concepts that students may hold. These include investigations by Osborne and Gilbert (1979) and Stead and Osborne (1980) who have used small samples of students and interviews to identify students' concepts.

Recently, research was conducted by Trowbridge and McDermott (1980, 1981) to investigate students' concepts of velocity and acceleration in one dimension. These students were enrolled in introductory physics courses at the University of Washington. Other research (Ichio Mori, Masao Koyima, and Tsutomu Deno (1976) and Phillips (1969)) has examined younger (2-11 years) children's concept of speed using Piagetian motion tasks.

This paper attempts to identify the concepts of speed, velocity and acceleration held by students in the 11-16 years old range.

METHOD OF INVESTIGATION

The method for obtaining the information from the students was an interview-about-events and interview-about-instances procedure developed by Osborne and Gilbert (1979).

Students in the interview were shown drawings on cards which represented various instances - car slowing down, car speeding up, a van overtaking a car, two boys starting from different places and finishing at the same place in the same time, and a ball dropped from an aircraft. The students were also shown events such as dropping the ball from a height of one metre, throwing a ball up, rolling a ball down an incline, and spinning a ball around on the end of a string (see Fig. 1).

The interviews were conducted to a standard questioning format, but at any point the interviewer could choose to probe more deeply into a student's understanding by extending the discussion. The standard questioning format was:

- (a) What can you tell me about the speed of the ... ?
- (b) Is the speed changing? ... If so where?
- (c) Has it got any velocity?
- (d) Is the velocity changing?
- (e) Has it got any acceleration? ... Why do you say that?

The sample consisted of thirty students from five different schools, three intermediate (11-13 years) and two secondary (13-16 years). The teachers were asked to send pupils of average ability to be interviewed. The interviews were taped and later transcribed to obtain a written record for detailed analysis. The sample was made up of:

- 6 Form 1 pupils (11-12 years): code numbers, 11 - 16
- 6 Form 2 pupils (12-13 years): code numbers, 21 - 26
- 6 Form 3 pupils (13-14 years): code numbers, 31 - 36
- 6 Form 4 pupils (14-15 years): code numbers, 41 - 46
- 6 Form 5 pupils (15-16 years): code numbers, 51 - 56

The students were interviewed in the final third of the year. Those at secondary school had all covered some form of study in kinematics but not immediately prior to the interviews.

To verify some aspects of the interview work using a much larger sample of students, a multichoice survey largely based on the interview schedule was administered to 113 third formers (12-14 years), 110 fourth formers (14-15 years), 96 fifth formers (15-16 years), 52 sixth form physics students and 56 non physics sixth formers (16-17 years). The survey was a simple one in which students' combinations of answers were analyzed. For example if they indicated speed was increasing did they also indicate that the acceleration was increasing? This approach meant that it could be seen if the student was answering each question consistently, and that they understood the initial question.

In this brief paper only the major findings of the work are discussed and exemplified.

STUDENT VIEWS OF SPEED

The concept of speed to these students was expressed in terms of distance travelled and the time taken. For example, the students were able to state that at constant speed travelling three times the distance would take three times as long.

1



CAR SLOWING DOWN

2



CAR SPEEDING UP

3



VAN ABOUT TO OVERTAKE CAR

4

BALL DROPPED FROM
1 METRE

5



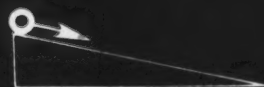
BALL DROPPED FROM AIRCRAFT

6



THROWING BALLS IN AIR

7

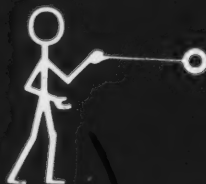


BALL ROLLING DOWN INCLINE

8

BOTH START AT THE SAME TIME IN DIFFERENT
PLACES AND FINISH AT THE SAME PLACE

9



SWINGING BALL AROUND

FIGURE 1. Instances and Events Used
during Interviews

In one of the speed comparison examples, two runners start in different places at the same time but finish in the same place at the same instant. All the students who were interviewed stated that the runner who covered the greater distance was going faster. However it appeared from the interviews that going faster was closely associated in some students' minds with catching up. For example, 'The back one would be going faster because he is catching up'. (33)

In the other speed comparison example, a van overtakes a car. The van and the car were both travelling with uniform speeds, but with the van's speed greater than the car's. During the course of the interview the students were asked whether the van and the car were ever travelling at the same speed.

'When the van is by the car'. (14,15,16,24,32,33,54)

Student: 'They are going the same speed when the van is parallel to the car'.

Interviewer: 'Why do you say that?'

Student: 'Because they are in the same place'. (33)

When students were asked how long they would be travelling at the same speed it was usually said to be a very short time.

'On about a tenth of a second'. (44)

'Maybe a second, not very long'. (25,54,55)

These students (11,14,15,16,24,25,26,31,32,33,35,44,46,54,44) seem to believe that when one object has caught up to another they must be going the same speed as the car, when in fact they had stated the van would be going faster just before. the typical reply was,

'Well for a split second they are at the same point and to get there they both need to go the same speed'. (31)

The results of the larger survey on a question related to this point (see Appendix Q.2) also reveal this general trend, as is shown in the table below.

Class Level	Van at same speed as car for 1/10sec.	Van faster than the car all the time
Third Form	80%	15%
Fourth Form	70%	25%
Fifth Form	68%	32%
Sixth Form (Physics)	32%	68%
Sixth Form	41%	59%

100

Phillips (1969) suggests that the passing phenomenon dominates over the 'terminal position' when the two are in conflict for young children (2-11 years). It

would appear from the above data that the passing phenomenon also dominates some students' ideas of relative speeds. Trowbridge and McDermott (1980) had similar responses from some college students.

STUDENT VIEWS OF VELOCITY

Students had varying views about velocity. Although the meaning of the word 'velocity' is not taught formally until the fourth form (14-15 years) it is interesting to find out what concepts students bring to the classroom. The students' meanings for the word 'velocity' could be placed into four categories.

1 'I don't know what velocity is'.

Thirteen of the students (12,13,14,21,22,24,25,26,31,32,37,44,55) didn't know what velocity was and could really make no comment.

2 'Velocity is the same as speed'.

Five students considered that speed and velocity were synonymous.

'They [velocity and speed] are both the same'. (35,36,41,46,54)

3 'Velocity is different from speed'.

Five students considered velocity different from speed, but the differences were not the accepted scientific ones.

'Well the velocity is the same as the acceleration'. (23,34,42)

'Velocity can be slowing down but speed, it is normally rising, but velocity can go both ways'. (51)

'Velocity is the direction it is going ...' (52)

Three other students (11,45,56) had other definitions for velocity, such as the speed of a bullet (muzzle velocity) and wind velocity.

4 'Velocity is speed in a certain direction'.

Only one student of those interviewed used the idea of velocity correctly when discussing the various events.

'Velocity is speed in a certain direction'. (55)

STUDENT VIEWS ON ACCELERATION

The main aspect of this work was to explore student views of acceleration. The events and instances depicted on the cards were the same as used throughout the interviews and the surveys. The ball dropping from one metre, throwing a ball up and rolling a ball down an incline, depicted instances of nearly constant acceleration, and a swinging ball, in which both the speed and acceleration were varied. The student were able to see the events and they could be repeated as many times as the student wished. The students were able to participate in the events themselves to get a clearer understanding of what was occurring. The students taking part in the survey

were unable to see the events taking place (a few tried some of the demonstrations themselves).

From the interviews it became obvious that the majority of students realized that acceleration involved the idea of a change in speed but the relationship between the two quantities was not the scientific definition (i.e., acceleration = change in speed/change in time).

For example when discussing the falling ball and the ball rolling down an incline,

'The acceleration will be increasing as it falls'. (11,13,21,25,33,35,43,51)

'It's falling - getting faster so acceleration getting larger'. (23,24,36,41,42,44)

'Cause it's following the incline and increasing in speed so acceleration is increasing'. (32,46,52,54,56)

Or when discussing the car that was speeding up.

'It's getting faster, increasing speed so more acceleration'. (24,31,33).

These students (11,13,21,23,24,25,31,32,33,34,35,41,42,43,44,46,51,52,54,55,56) all assumed that increasing speed always meant increasing acceleration.

The results of the larger survey using questions to probe these ideas (see Appendix Q.5-6) also indicated that this view appears to be widely held by many students.

TABLE

Percentage associating increased acceleration
with increase in speed.

Class Level	Increasing speed = Increasing acceleration
Third Form	88%
Fourth Form	80%
Fifth Form	80%
Sixth Form	75%
Sixth Form(Physics)	60%

Some students (12,13,14,15,16,22,26,31,32,43,45) however indicated that if an object was going fast it also had acceleration.

'Going the same speed it's still got some acceleration'. (12,19,22,26,32,43).

This idea especially in young children may have originated from the use of the word 'accelerator pedal' in a car.

'Still got to keep foot on accelerator pedal to keep the same speed'. (16,43)

Only one student interviewed had an understanding of acceleration: $\frac{\Delta v}{\Delta t}$;

'It's velocity is increasing but it is accelerating at the same rate'. (53)
(falling ball)

With the swinging ball example (Figure 1, No.7) those students that indicated that increasing speed was increasing acceleration, stated that the ball had acceleration when it was starting from rest through to top speed. However when it reached top speed they stated that it didn't have any acceleration. This is understandable if students have little or no understanding of velocity. The one student who seemed to have a good understanding of speed, velocity, and acceleration stated that the swinging ball had no acceleration at constant maximum speed. The reason for this was

'The velocity is the circular direction'. (53) (swinging ball)

DISCUSSION

This investigation has been useful in identifying some students' ideas about speed, velocity, and acceleration.

The phenomenon of two objects being the same speed when passing was evident in all age groups. The students generally didn't understand what velocity was, even those students who had studied it in the formal classroom setting. Acceleration was perceived by the students to be increasing if the speed was increasing. The students generally failed to take the corresponding time interval into account. Students of all ages could be found in each of the categories for speed and acceleration.

The swinging ball example may have been too difficult for students of this age group, particularly when they did not have an understanding of velocity. It did however reveal some of the students' ideas about acceleration with respect to constant speed.

Although the interviews were conducted over a small sample, the larger survey did validate the major aspects of the interviews. The results were similar to those of Trowbridge and McDermott (1980, 1981) who interviewed older first year college students.

While the interview work did not focus on the views of senior secondary school physics students the study does have direct implications for physics teaching at that level. For example recently one senior physics class (6 form) were asked if they considered an object falling or rolling down a slope to have increasing acceleration. Despite the fact that these students had just been taught the theoretical aspects of acceleration, seventy per cent answered that it would. As a result of the above information extra time was spent on the topic and a series of experiments and demonstrations were used to establish in the pupils' minds the physicists' view of acceleration.

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APPENDIX

A Survey on Your Ideas About Various Events

Instructions

- 1 Choose the answer that best describes your ideas about the various events.
- 2 Please answer every question.
- 3 Do not mark the question paper.
- 4 This is not a test.

Questions 1-2. A van is passing a car on the motorway.

- 1 Which vehicle is travelling the faster?
 - (a) van
 - (b) car
 - (c) both travelling the same speed
- 2 At the instance that the van is level with the car, which is going the faster?
 - (a) both the same speed
 - (b) both the same speed but only for a short time, e.g. one tenth of a sec.
 - (c) van
 - (d) car.

Questions 3-4. A ball is dropped from one metre.

- 3 What is happening to the speed?
 - (a) increasing
 - (b) decreasing
 - (c) speed remains the same all the way down.
- 4 What is happening to the acceleration?
 - (a) increasing
 - (b) decreasing
 - (c) remains the same.

Questions 5-6. A ball is rolling down a slope.

- 5 What is happening to the speed?
 - (a) decreasing on the way down
 - (b) increasing on the way down
 - (c) same all the way down after being released.
- 6 What is happening to the acceleration?
 - (a) increasing
 - (b) decreasing
 - (c) same acceleration all the way down.

Questions 7-10. A ball is thrown into the air.

- 7 On the way up is the speed
- (a) increasing all the way up
 - (b) decreasing all the way up
 - (c) doesn't change.
- 8 On the way down the speed is
- (a) increasing all the way down
 - (b) decreasing all the way down
 - (c) same speed all the way down.
- 9 On the way down the acceleration is
- (a) increasing all the way down
 - (b) decreasing all the way down
 - (c) remains the same all the way down.
- 10 On the way up the acceleration is
- (a) increasing
 - (b) decreasing
 - (c) remains the same.

STUDENT BELIEFS ABOUT PLACE VALUE AND DECIMALS: ANY RELEVANCE FOR SCIENCE EDUCATION?

Ken Carr

INTRODUCTION

The major thrust in the teaching of mathematics in recent years has been understanding the subject as an open on-going process, but in spite of attempts to provide primary children with meaningful experiences in mathematics many students are not achieving acceptable levels of competence (Brown, 1978).

What's Being Done

In attempts to understand why this is so, research at the University of Waikato on student conceptualizations in arithmetic has focused on place value and decimals. Initial surveys based on tests used in Britain by Brown (1981a, 1981b) were administered to a representative sample of 100 11-14 year old students. Response patterns revealed areas of student difficulties, and stimulus cards based upon the more common errors were created (c.f. Osborne *et al.*, 1982). Cards were trialled, modified, and finally 18 stimulus cards were used in interviews with 11-14 year olds.

These 18 cards were used to explore students' ideas and beliefs about place value and decimals. More specifically, the cards were concerned with estimation,

e.g.

0.8 is nearest in size to?				
1.8	.08	8	1	0

with dividing by 10, 100 and 20; with asking students to write decimal fractions (such as three tenths, fifteen hundredths, etc); with requiring students to generate an algorithm that would solve a problem in a verbal form (involving decimal fractions) and finally with comparing two numbers (e.g. 123 and 12.3).

Students were probed on their attitude towards mathematics, the difficulties they experience in other facets of mathematics and, asked to name the columns on either side of a decimal point.

In 1981 a sample of 30 Form I and Form II students (aged 11-12 approximately) were interviewed with the above stimulus cards. The sample was representative in

terms of sex, school achievement in mathematics, general scholastic attainment, and ethnicity. The interviews were flexible enough to explore individual ideas and beliefs. In short, idiographic assessment procedures were used to elicit information that nomothetic procedures could not.

In 1982, after an average time interval of 14 months, 28 of the original sample were interviewed a second time. These second interviews were based again on the stimulus cards described earlier. This longitudinal design was considered appropriate as the aim was to monitor in detail individual changes (Erlwanger, 1975). Much of the methodology has been based on that of the Learning in Science Project at the University of Waikato (Osborne et al., 1982).

What's Been Found

Students when re-interviewed often display similar response patterns to the previous interview. For some segments of the interviews, transcripts show word-for-word duplication of the interview made 14 months earlier. The major finding has been that students retain misconceptions over the period surveyed thus far. In this longitudinal sample, the most common response typology was from incorrect-to-incorrect. Some of the misconceptions will now be discussed.

Twelve of this representative sample of 28 12 and 13 year olds still cannot correctly name the place value columns for decimal fractions. The most common error is to mirror image the whole number nomenclature. In other words, the first digit in a three place decimal fraction is 'ones' or 'onehs', the second digit 'tens' or 'tenths', and the third digit 'hundreds' or 'hundredths'.

As a corollary of this, students have problems writing decimal fractions. In the sample, only eight students could correctly write the decimal fractions for three tenths, seven hundredths, fifteen hundredths, seventeen tenths, and twenty hundredths. The following sequence illustrates typical confusions (I = Interviewer, S = subject).

- I Seven hundredths. Could you write seven hundredths?
(Seven hundredths written on card in front of S.)
- S Point oh oh seven (writes '007').
- I How did you work that out?
- S Well, I've done it in hundredths. Hundredths is two zeros. So I put decimal, two zeros, and then the seven.
- I Why?
- S Well, a hundred has two zeros.

In comparison Brown (1981b) notes that 50 per cent and 60 per cent of 12 and 13 year olds (respectively) in Britain could write the decimal fraction 'three hundredths'.

When it came to division algorithms that would yield a decimal fraction quotient (i.e. when the divisor was larger than the dividend) less than half the sample could correctly compute an answer. Some students believed that negative integers might be one way out of the dilemma. The following extract illustrates this:

- I: What's fifteen divided by a hundredth?
 S: Can't [do it].
 I: Why not?
 S: Well, a hundred's more than fifteen.
 I: Is there any way you can do it? Any way you can think of?
 S: ... unless you go minus ... minus eighty-five. You get to zero, and then go minus one, minus two, minus three ... You wouldn't really be able to do it, because it's not really anything, minus eighty-five.

When asked to compare two numbers (e.g. 12^2 and 12.3) half of the sample were able to say that one number was ten times greater than the other, and give a mathematically correct explanation for this. Obviously, not all 12 and 13 year olds can understand the 'adult rule' of simply shifting the decimal point, or digits around the decimal point, to change a number's size 'courtesy of' our base ten system of numeration.

What Relevance for Science Education?

To the extent that an understanding of basic concepts in the place value of numbers is important for students learning science, this research will have relevance for science teachers and science teaching. Certain topics in Science Education obviously use numerals and numbers to a large extent. For example, Harlen (1979) lists goals for earlier development and later development in science, amongst these concepts to do with weight, length, area, volume, force, etc (c.f. Hart, 1981). The question remains, what will 50 per cent of 13 year olds understand when they compare a measurement of, say, 247 units with 2.47 units?

Making predictions based on observations is part of the primary school science syllabus for New Zealand schools (Science Syllabus, 1975, p.21), and experiments with predicting the extension of a coil spring are described. For instance:

Mass g	Extension cm
0	0
10	1.0
25	2.5
30	3.0

(Science Syllabus, Primary to Std 4, p.21)

From a graph, it is hoped that students will predict accurately. However, if research suggests that many 12 and 13 year olds have incorrect ideas about numbers with decimal fractions, then the prognosis for Standard 4 students (10 year olds) understanding this particular experiment cannot be encouraging. The point scarcely needs labouring.

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BEGINNING STUDENT TEACHERS' OPINIONS ABOUT TEACHING PRIMARY SCIENCE

Ken Appleton

INTRODUCTION

Science in the primary school has been called the 'Cinderella' subject, and with good reason. Surveys have revealed that a fair proportion of teachers do not teach science, and that many teachers use strategies such as lectures, class discussions and watching science television programs rather than involving children in actual investigations (Symington, 1974; Varley, 1975). As the newer primary science programs now put considerable emphasis on children being involved in hands-on experiences, teacher educators have attempted to identify and find means of overcoming the problems for teachers in the teaching of science. The problems are many, but there is some agreement that a central problem is the attitudes of teachers to science and to teaching science (Bratt, 1977; Bollen, 1972; Appleton, 1977; Dawes, 1982). Teacher educators have therefore endeavoured to ensure that positive attitudes are being developed in pre-service teacher training courses (e.g., Bratt, 1977; Lucas and Dooley, 1982; Appleton, 1983).

However, the problem of teacher attitudes has several facets. Firstly, there are several attitudes to consider:

- . attitudes to science
- . opinions about the appropriateness of strategies such as hands-on activities
- . self-confidence in teaching science using appropriate strategies
- . beliefs about the relative importance of science compared to other curriculum areas.

Some of these attitudes may overlap or be related, but little research seems to have been done to clarify this.

Secondly, there is the question of where and how these attitudes originate. Some assumptions have been made about this (Appleton, 1977; Lucas & Dooley, 1982) but little seems to have been clearly established about teaching strategies and self-confidence (Morrisey, 1981).

Thirdly, there is the question of which of these attitudes most influence the frequency of teaching science, and the strategies used. Sunal (1982) suggested that

attitudes to science were not as closely associated with frequency of science teaching as attitudes to learning and to teaching science.

Some studies have been designed with the apparent assumption that teachers, and therefore student teachers, hold negative attitudes towards teaching science (Morrisey, 1981; Lucas & Dooley, 1982).

While it has been established that some attitudes such as perceived adequacy to teach science (Perkes, 1975) have their origins in pre-service teacher education, it is not clear whether student teachers' opinions about the use of hands-on teaching strategies are formed during pre-service training or prior to it. Findings by Bollen (1972) suggest that they may be formed prior to training, yet it would be reasonable to expect such opinions to be formed during a period of study of teaching strategies rather than during secondary schooling. Any such attitudes which are formed at high school seem to be negative ones (Lucas & Dooley 1982). This study attempted to identify opinions (if any) of beginning student teachers about various teaching strategies in primary science, and to identify relationships between these and selected background characteristics. All beginning students (90 students) in the Diploma of Teaching course at the Capricornia Institute of Advanced Education were surveyed during orientation week regarding their opinions of various teaching strategies in science. The questionnaire consisting of fifteen Likert-type items was adapted from an instrument used by Tisher and Power (1975) and focussed on the following five dimensions relating to strategies in teaching science:

- (a) the nature of classroom experiments
- (b) the focus of the science learning
- (c) the type of learning activities
- (d) the method of grouping pupils
- (e) the major source of information in science.

Table 1 lists the items in the questionnaire. Background information about gender, age, and amount of science studied at high school was also obtained. Subsequent to the administration of the questionnaire, a number of students were interviewed regarding the origins of their opinions.

TABLE I
Questionnaire Items

What degree of emphasis do you think you would put on :

- pupils devising and conducting their own experiments where possible?
- the teacher demonstrating most experiments?
- pupils using worksheets as a guide to experimental activities?
- giving children practice in the thinking skills in science (such as observing, inferring, predicting)?
- Encouraging children to remember important facts in science (such as the different parts of a flower)?
- helping children develop understandings of the important ideas in science (such as photosynthesis in green plants)?
- the teacher explaining to the pupils what they need to know?
- the pupils watching weekly science programs on television?
- experimental activities done by the pupils themselves?
- pupils doing the same science activity, but carried out by different groups in the class?
- pupils doing the same science activity, with the class as a whole?
- pupils doing different science activities, and carried out by different groups in the class?
- first-hand experiences with phenomena, by the children, as the major source of information in science?
- books and notes as the major source of information in science?
- the teacher as the major source of information in science?

Ninety-two per cent of the questionnaires were returned, and six post-questionnaire interviews were conducted. Most of the interviews were conducted with the students before they commenced any science education units.

SURVEY RESULTS AND DISCUSSION

The background information revealed that this group of students was similar to other pre-service students, except that there was a slightly higher proportion of male students (24 per cent).

Each Likert scale item was coded from 1 (little or no emphasis) to 5 (a great deal of emphasis); frequency distributions for each item were obtained, and means and standard deviations were calculated.

TABLE 2
Ranked Items With Descriptive Statistics

No.	Item Description	Mean	Standard Dev.	Frequency (%)				
				1	2	3	4	5
4	Children learn process skills	4.39	0.66	0	0	10	41	49
13	First hand experiences for information	4.07	0.93	1	4	21	35	40
9	Pupil experimentation	3.94	0.93	0	7	24	27	32
7	Teacher explaining	3.91	0.88	0	7	20	44	28
10	Same activity, different gps.	3.79	0.86	1	4	30	44	21
6	Children learn concepts	3.72	0.87	0	7	33	40	20
1	Pupils devise experiments	3.63	0.91	1	7	37	36	18
3	Worksheets as experimental guides	3.57	1.03	2	11	35	29	22
14	Books & notes for information	3.37	0.78	1	8	49	35	6
15	Teacher as information source	3.30	1.01	2	17	43	22	15
5	Children learn facts	3.28	0.79	1	13	45	37	4
12	Different activities, different groups	3.22	1.13	6	21	32	26	15
2	Teacher demonstrations	3.01	0.90	5	21	46	24	4
8	Children watch T.V.	2.98	0.94	4	28	42	20	6
11	Same activity, whole class	2.98	0.72	1	23	52	23	0

Table 2 summarizes these figures with items placed in rank order of means. The first three items in the rank ordering are all items which relate to the use of hands on activities in science. The items which relate to teacher domination and control tend to be in the lower half of the rank order, with the exception of item 7 (teacher explaining what the children need to know). These results clearly indicate that the beginning students had already formed very definite ideas about the various strategies, and that those ideas generally favoured the use of hands-on strategies in primary science.

Biddulph (1982) found that primary teachers tended to perceive their main task in teaching science as leading children to their own pre-determined answers and solutions and that activity work is used within that context. This tendency seemed to be reflected in the above results where the item on teacher explaining scored fairly highly. Some other explanations for this could be that the students feel that children cannot perform activity work without explanations from the teacher, or that after the activity the teacher needs to explain its relevance. An alternative explanation that the teacher needs to explain a lot of information which has no relationship to the practical work at hand does not seem likely considering the lower emphasis on the teacher as an information source (item 15).

Another interesting feature is the placement of item 12, the use of different groups doing different activities. This item could reasonably be expected to be associated with hands-on work, or at least with children devising their own experiments (item 1), yet it was rated relatively lowly. By comparison item 10, the children doing the same activity but in different groups, was rated highly. This suggests that the students felt a need for some teacher control over activity work. This demand by the teacher for more control over group work was also reported by Biddulph (1982), in that teachers seem to need to feel that they have definite control over what happens in the classroom. The result also suggests that factors other than a belief in hands-on activity work determine the type of grouping employed in a classroom. In the case of these beginning teachers, it may be that they have never experienced in their own schooling an organization where different groups perform different activities.

BACKGROUND CHARACTERISTICS

In order to identify any relationships between questionnaire items and the selected background characteristics, multiple regression analyses were conducted using each item as a dependent variable, and gender, age, and school science background as independent variables.

Of the fifteen analyses conducted, only one produced any statistically significant results. Item 3, the use of worksheets as a guide to experimental activities, showed a significant linear relationship with two independent variables. The relationships were positive, but the goodness of fit was not particularly strong. Table 3 lists the relevant regression data. This relationship seems to suggest that female students who have studied more science at high school would put greater emphasis on the use of experimental worksheets. This may reflect the nature of laboratory exercises in science subjects preferred by women in the secondary school. In Queensland women seem to prefer biology, which is predominantly 'Web of Life' oriented.

TABLE 3

Regression Analysis

Dependent variable: Item 3 - Use of Worksheets

Multiple R: 0.343 F ratio: 3.38(p<0.05)
 R^2 : 0.118 df: 3,76

Independent Variables	Beta	F
Gender	0.282	6.73
High School Science	0.261	4.56
Age	0.100	0.68

It is also worth noting some of the non-significant results from the regression analyses. If attitudes to teaching science have their origins in the high school, then it would be reasonable to postulate either a positive or a negative relationship between variables relating to hands-on strategies, and the amount of science taken at secondary school (Morrisey, 1981). For example, students who have taken three science subjects could be expected to be more committed to hands-on science than students who have taken only one subject, if science programs do generate favourable attitudes. However, the lack of significant relationships between the amount of high school science and any hands-on teaching strategy variables refutes such a postulate.

TRACING THE ORIGINS

From the above results, a quite pertinent question arose: Given the existence of a generally high commitment to hands-on science by the students, where was that commitment formed?

Intuition would suggest that it must have some origins in the students' own schooling - but what aspects of that schooling were relevant? In order to explore the questions, follow-up interviews were conducted with six students. The interviews were open-ended, using the questionnaire as a starting point and with anonymity being retained as much as possible.

Aspects explored were :

- (a) The student's general response to the hands on items on the questionnaire;
- (b) Particular incidents or circumstances in the past which the student felt influenced his/her ideas about those strategies;
- (c) Whether the student had ever personally experienced hands-on science.

INTERVIEW RESULTS

All interviewees had given reasonably high emphasis to hands on strategies in the questionnaire, and reported that the main influence on their opinions had been their own schooling. From the range of experiences they had encountered in their own learning, they were firmly convinced that they had learnt more from hands on experiences than from any other strategies. The interviewees had all at some time experienced some hands on activity work. Those who had experienced a fair amount of hands-on work were definitely in favour of it. Those who had experienced very little hands-on work were adamant that such strategies should be used. As one interviewee put it :

"I wouldn't want to inflict any of the children I teach with what I had to put up with!" (referring to teacher telling strategies experience in year 8).

Three of the interviewees volunteered the information that they had disliked science in secondary school. One of these expressed extreme emotional reactions to her experiences.

Another less important factor reported by three interviewees was their own observations of children's enjoyment and learning from hands-on situations. The children observed had been either younger siblings or the interviewee's own children.

As the sample of students interviewed was small some bias could be present in these findings. However this is less likely considering the uniformity of the results. A wider-based interview program is currently being conducted as a check on these preliminary findings.

CONCLUSIONS

Beginning student teachers have already acquired very definite views about teaching science before they begin their teacher training course. These views are generally similar to the views espoused by science educators, but are contrary to the classroom practices of many teachers. Their views seem to have origins in what the students perceive to have been meaningful and enjoyable learning experiences for themselves in their own schooling; and to a lesser extent for children they have observed. Female students who have studied more science at high school tend to favour the use of worksheets in experimental work. Several interesting questions arise from these findings:

When these students begin to teach as qualified teachers, will they still espouse the same opinions?

If so, does that mean that there is a 'new wave' of teachers entering the service who are more committed to hands-on activity work than their older colleagues?

If not, what aspects of the teacher training process have caused them to change their opinions?

Will these present students be using hands-on strategies themselves after they have been teaching for some time? That is, do system and school constraints effectively prevent teachers from using such strategies?

Can secondary science teachers do more to influence positively their students' opinions about teaching science, such as engendering more positive attitudes to science, incorporating more hands-on work, and relying less on printed worksheets in laboratory work?

This exploratory work has highlighted the concern expressed by Morrissey (1981) in that there is a great need for long term longitudinal studies of student teachers' attitudes to teaching science, with a particular focus on their teaching behaviours after graduation.

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TEACHER BEHAVIOURS AND STUDENT TASK INVOLVEMENT WITHIN
SMALL GROUP AND INDIVIDUAL ACTIVITY SETTINGS

Warren Beasley

INTRODUCTION

A major goal of the Science Classroom Management Project (Butler *et al.*, 1980) was to identify the management practices of high school science teachers that maximize the time students were actively engaged in learning activities. Although the basic guiding constructs in the Science Classroom Management Project are derived from the ecological psychology of Barker (1968), it is clear that the setting alone is not sufficient to cause a common level of task involvement (Butler *et al.*, 1980; Beasley, 1983). Rather, the teacher must have various bundles of techniques and must appropriately apply these techniques differentially to the different activity niches (Kounin and Sherman, 1979). This paper describes the classroom management behaviours of junior high school science teachers within learning settings characterised by small group laboratory activities and individual problem solving activities. This description includes analysis of the relationship between teacher management behaviours and student task involvement.

METHODOLOGY

All observations in the Science Classroom Management Project were made in a regular science classroom setting. The sample of teachers and their students came from 24 science classrooms in six Brisbane high schools. There were three Year 8 classes, twelve Year 9 classes and nine Year 10 classes with a median class size of 27 (range 20-36).

There were 16 men and eight women teachers. The teachers volunteered to participate in the study after the project was described at meetings of the junior science teachers in each school.

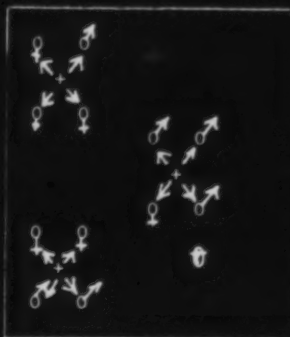
It was planned that each teacher would be observed giving four science lessons, each about a month apart. Ninety-one of the intended ninety-six lessons were recorded. Each lesson was recorded on two videotapes. One tape was made by a mobile camera with a zoom-lens that tracked the teacher from a position at the back of the classroom (Teacher Tape). The other tape was derived from a fixed camera with a wide-angle lens, in a corner at the front of the room facing the students

(Student Tape). The teacher wore a cordless radio microphone, and there were two omnidirectional microphones on floor stands among the students. The total input from these three radio sources constituted the soundtrack on the video tapes.

The ninety-one lessons were coded into distinct lesson segments. This was essential because it has been argued (McCaw *et al.*, 1973; Medley, 1979) that the 'whole lesson' is an inadequate unit. These segments of lessons were defined as time periods of variable length which were characterized by distinct complementary sets of teacher/student behaviours. Those segments which possessed the characteristics of individual activity or small group activity (Table 1) are analysed in this paper.

TABLE 1

SMALL GROUP ACTIVITY (SGA)

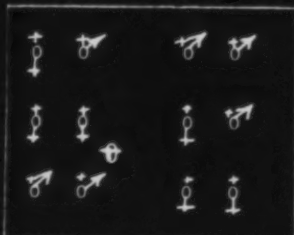


CONSTITUENT STUDENT BEHAVIOUR

- . Do experiment. Observe. Record
- . Discuss with other students.
- . Stay in group. Ask teacher for help.

Experiment is focus for student attention; it and other students are signal sources.

INDIVIDUAL ACTIVITY (IA)



CONSTITUENT STUDENT BEHAVIOUR

- . Write. Read. Work alone.
- . Ask teacher for help.
- . Be quiet. Stay in seat.

Problems are focus of student attention; the signal source is on the desk.

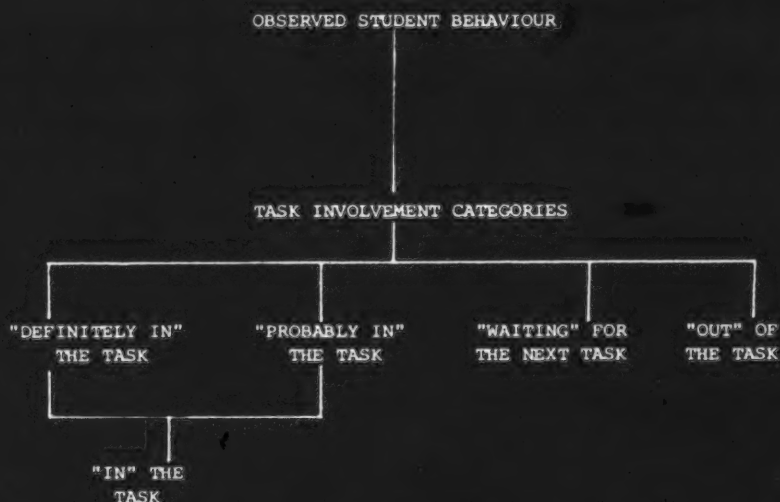
Observing student behaviour

The ninety-one student tapes were coded for student task involvement (Kounin, 1970; Butler *et al.*, 1980). The categories for task involvement were given in Figure 1. Very full definitions and examples of the categories are given in Kounin

(1970). Briefly, students were scored 'definitely in' if they exhibited overt signs of direct compliance with the instructional or organizational task set by the teacher; 'probably in' if it could be reasonably inferred that they were engaged in the task; 'waiting' if they completed the teacher's task and there was no further task; 'definitely out' if they clearly showed signs that they were not engaged in the prescribed activity; 'in' is simply the sum of the 'definitely in' and 'probably in' scores.

FIGURE 1.

Students task involvement categories
used to code the behaviour of students
in science lessons.



Six students were selected for observation from the videotape (Student Tape) following a procedure that assured equal representation from all regions of the room. The behaviour of these students was coded by six trained coders whose observer agreement coefficients had a mean of 0.72 (Butler *et al.*, 1980). Each of the six students was coded continuously throughout the observed lesson.

The reliability (Medley and Mitzel, 1963) with which task involvement was observed in the twenty-four classrooms was determined by calculating the intraclass correlation coefficient (Rowley, 1976). The reliabilities of the mean task involvement scores for four observations in each classroom ranged from 0.63 ('probably in') to 0.82 ('waiting'). These high values indicate that the levels of task involvement in the twenty-four classrooms were observed to be reasonably stable across four observations (Butler *et al.*, 1980).

Observing teacher behaviour

These overt low inference teacher behaviours which allowed the question 'What is the teacher doing now?' to be answered were categorised. These categories of behaviour are described in Table 2. These behaviours overlap consistently with those described in the Science Laboratory Interaction Categories instrument developed and validated by Kyle *et al.*, (1979). An ongoing log was kept, on a time base, of the teacher overt management behaviours. This was achieved by utilizing observer controlled electronic button boxes which recorded each behaviour category as it occurred. The time each teacher spent in these operational modes listed in Table 2 was recorded continuously.

Although students were required to operate as members of a small group during laboratory investigations or alone during individual activity tasks, the science teacher's actions are directed either for whole class attention, or for small group attention or for an individual student's sole attention.

Thus the first six categories of teacher management behaviours described in Table 1 (Organisation to Sociation) can be applied at three levels. These are teacher-whole group, teacher-small group or teacher-individual student. The final three teacher behaviour categories listed in Table 2 (walking, equipping, non-lesson related) are not directly intended for student attention.

The data were coded continuously and are representative of the proportion of time students were involved in the task (within Individual Activity or Small Group Activity settings) and the corresponding proportion of time teachers were involved in each of the management behaviours respectively. Pearson correlation coefficients were calculated for Student Task Involvement versus Teacher Management Behaviour.

RESULTS

Teacher behaviour during small group laboratory activities and individual activities is presented under three headings:

- (i) involvement with class as a whole;
- (ii) involvement with a small group or individual within the class;
- (iii) no involvement with any students.

Table 3 presents the correlation coefficients for the teacher management behaviour (directed for whole class attention) and the student task involvement during small group laboratory investigation settings. The significant correlations relate to those teacher initiated actions of providing information, or being in a prominent position to monitor the class as a whole. Although the students were

TABLE 2

Categories of Teacher Management Behaviours

TEACHER OVERT BEHAVIOUR	CHARACTERISTICS
Organization	Gives special directions about the activity, group structure, location of equipment, etc.
Exposition	A teacher initiated activity in which information is given to students either verbally (e.g. question/answer, statement, dictation) or written (e.g. blackboard summary) or by demonstration (e.g. Techniques in setting up apparatus)
Explanation	A teacher response to an action initiated by a student (e.g. question answered, equipment demonstrated)
Order	Makes statement which changes behaviour of students or related to standard of behaviour expected
Surveillance	Teacher holding self in readiness while waiting for students to complete a task, or listening to student response or surveying whole class group
Sociation	Discussion which is not relevant to the immediate classroom activity (e.g. results of school sporting events)
Walking	Teacher movement which is deliberate and with the purpose of simply moving from A to B
Equipping	Getting equipment and materials which are not immediately available for student collection (e.g. ice from refrigerator, replacing faulty meter from storeroom supply)
Non-lesson related	Teacher presence is not directly related to classroom activity (e.g. answering inquiry at the door, gazing out of the window).

organised for small group activity, teacher actions directed for whole class attention were related to a higher degree of task involvement by students.

TABLE 3
Correlation Coefficients: Small Group Setting
Whole Class Teacher Management Behaviour and
Student Task Involvement

		Teacher Management Behaviour observed					
		Organisation	Explanation	Exposition	Surveillance	Order	Sociation
STUDENT TASK INVOLVE- MENT	Definitely in	0.17	0.08	0.49*	0.49*	-0.25	-
	Probably in	-0.21	0.01	-0.27	-0.31	0.37	-
	In	0.08	0.10	0.45*	0.43*	-0.09	-
	Waiting	0.32	-0.09	-0.22	-0.27	-0.15	-
	Out	-0.10	-0.08	-0.41*	-0.39*	0.15	-

* $p < .05$

Table 4 presents the correlations between teacher management behaviour (directed for a small group's attention) and student task involvement during small group laboratory investigation settings. The significant correlations represent those teacher behaviours which are responding to a student initiated inquiry. These teacher behaviours were associated with periods of lower student task involvement of the class overall.

TABLE 4
Correlation Coefficients: Small Group Setting
Small Group Teacher Management Behaviour and
Student Task Involvement.

		Teacher Management Behaviour Observed					
		Organisation	Explanation	Exposition	Surveillance	Order	Sociation
STUDENT TASK INVOLVE- MENT	Definitely In	-0.04	-0.47*	0.09	-0.04	-0.30	0.00
	Probably In	0.25	0.17	-0.13	0.16	0.22	-0.26
	In	0.10	-0.49*	0.04	0.05	-0.24	-0.16
	Waiting	-0.17	-0.05	-0.04	0.51*	-0.05	-0.08
	Out	-0.04	0.17*	-0.05	-0.21	0.29	0.21

* $p < .05$

TABLE 5

Correlation Coefficients: Small Group Setting
Teacher Non Student Related Behaviour and
Student Task Involvement

		Teacher Behaviour Observed		
STUDENT TASK INVOLVE- MENT		Walking	Equiping	Non-lesson related
	Definitely in	-0.17	-0.21	0.32
	Probably in	0.28	0.09	-0.17
	In	-0.04	-0.21	0.29
	Waiting	0.11	0.54**	-0.15
	Out	0.02	0.02	-0.29

** $p < .01$

TABLE 6

Correlation Coefficients: Individual
Activity Setting
Whole Class Teacher Management Behaviour
and Student Task Involvement

		Teacher Management Behaviours Observed		
STUDENT TASK INVOLVE- MENT		Organis- ation	Explan- ation	Surveill- ance
	Definitely in	0.22	-0.01	0.55**
	Probably in	-0.19	0.50**	-0.31*
	In	0.18	0.42*	0.51*
	Waiting	0.11	-0.17	0.08
	Out	-0.21	-0.37*	-0.54**

* $p < .05$

** $p < .001$

TABLE 7

Correlation Coefficients: Individual Activity
Setting, Individual Student-Teacher Management
Behaviour and Student Task Involvement

		Teacher Management Behaviours Observed				
		Organisat- ion	Explanat- ion	Exposit- ion	Surveill- ance	Order
STUDENT TASK INVOLVE- MENT	Definit- ely In	-0.15	-0.18	-0.21	-0.32**	0.02
	Probably In	-0.23	-0.01	0.19	-0.01	-0.21
	In	-0.31	-0.23	-0.13	-0.46**	-0.09
	Waiting	0.47	-0.19	-0.21	0.28	0.24
	Out	0.17	0.13	0.18	0.39**	0.05

* $p < .05$

TABLE 8

Correlation Coefficient: Individual Activity
Setting, Teacher Non Student Related Behaviour
and Student Task Involvement.

		Teacher Behaviour Observed	
		Walking	Non-lesson related
STUDENT TASK INVOLVE- MENT	Definitely In	0.20	0.19
	Probably In	-0.23	-0.16
	In	0.07	0.14
	Waiting	0.29	0.26
	Out	-0.17	-0.23

Table 5 shows the teacher action of obtaining additional equipment for student use was associated with lower task involvement by group numbers. No other non-student related teacher behaviour was related to student task involvement.

Tables 6 to 8 present the correlation coefficients of teacher behaviour and task involvement during individual activity settings. The results in Table 6 relate to actions of the teacher directed at the whole class. The significant results suggest the teacher behaviours of explanation and surveillance are related to a higher task involvement by students.

The results in Table 6 are consistent with the significant result presented in Table 7. Where the teacher actions were directed at individual students alone, there was an overall lower class task involvement.

The correlation coefficients for teacher non-student related actions during individual activity settings are presented in Table 8. No significant relationships were observed.

DISCUSSION

The results in Tables 3 and 4 raise issues concerning the nature of pupil behaviour in small group laboratory activities. If independent group investigation is to be valued then the involvement of the teacher at the whole class level seems hardly appropriate. Yet these results suggest higher student task involvement in small group activities is associated with a teacher whole-class presence.

These findings are consistent with those reviewed by Power (1977). In the laboratory setting teacher talk remains a prevalent activity (30-50 per cent). Tisher and Power (1973, 1975) studied the relationships between measures of the educational values and preferred practices of teachers and their behaviour in ASEP classrooms. It was found that teachers foster activities in science lessons which are congruent with their beliefs about teaching. These teachers are what Eggleston and Galton (1976) would describe as having an 'actor-manager' style (enquiry-based lessons with transactions initiated by the teacher).

The teacher behaviour described as surveillance (Table 2) was also significantly correlated with pupil task involvement. The teacher was seen to be in a position of being able to 'survey' or 'interact' with the class as a whole group. This behaviour could be classed as being similar to Kounin's (1970) description of 'withitness'. Students, perceiving that the teacher was in a position to know what was going on around the room and being able to interact with the whole class at that time, responded by undertaking the required task.

The significant correlation in Table 5 is predictable. Teacher time spent during the lesson in servicing the equipment needs of students will be associated with students' waiting (for the equipment) to complete the task.

In moving to individual activity settings, the results presented in Tables 6 and 7 are congruent with those presented in Tables 3 and 4. Those teacher management behaviours which portray a whole-class presence are associated with higher task involvement. When the teacher acted at the individual student level, a lower overall class task involvement was evident.

These sets of results suggest that classes operating within small group or individual activity settings are effectively managed by teachers whose behaviour is more whole-class centred. Those teachers who initiate interactions with students and are not 'trapped' by particular groups or individuals into spending a disproportionate amount of time in any one activity are associated with classes with a higher student task involvement. It would seem that teachers observed in the Science Classroom Management Project believe and practise what Power (1977) reported about previous studies of science classroom interaction.

A certain amount of structure in science lessons does seem to be essential for many pupils - if one is seeking to foster the meaningful acquisition of content.

These observations raise the question of what is meant by effective learning in small groups or individual activity settings. Effectiveness as measured in this study has been taken to be high levels of student task involvement. Those classes who attained high levels of task involvement were associated with teachers who managed the class through whole class surveillance, verbal interaction and by teacher initiated interaction.

Given that the mean level of task involvement for the category 'in the set task' was 82 per cent with a standard deviation of 12, it would be possible to make a value judgement about teacher management practice, student task involvement and the nature of the learning setting. If one wished to manage science classrooms during laboratory activity periods in a way which allowed students to initiate more interactions and the teacher less, a lower level of pupil task involvement may be a consequence. This appears to be the trade-off for what self-paced student activity curriculum projects must expect. It could be that teachers operating in a small group or individual activity settings do not practise what Kounin (1970) would describe as 'over-lapping' management techniques, i.e., the ability to interact at the level of pupil activity within the setting and maintain an effective management function with the remainder of the class.

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DEVELOPMENT OF A SET OF SCALES TO MEASURE SELECTED SCIENTIFIC ATTITUDES

Bruce Jones and Bill Butts

The development of positive attitudes towards science has long been accepted as a legitimate goal of science education (Gauld, 1982; Gauld and Hukins, 1980; Haladyna and Shaughnessy, 1982). Fraser (1977), in a systematic scrutiny of the science education periodical literature, identified in 117 articles, a total of 1,547 aims statements of which 276 or 17.8 per cent were classified as attitudinal.

It is now generally acknowledged in the literature that the science related attitudes mentioned in such goal statements do not form a single unidimensional construct. Various writers have attempted classifications. Gardner (1975b) referred to 'attitudes towards science' (including such aspects as attitudes towards scientists and interest in science) and 'scientific attitudes' (such as openmindedness, scepticism etc). In further examining this latter construct Gauld and Hukins (1980) concluded that 'the components of the scientific attitude mentioned in the literature seem to fall into three broad groups'. These groups are (i) general attitude towards ideas and information, such as curiosity, openmindedness, scepticism; (ii) attitudes related to the evaluation of ideas and information, generally labelled as critical mindedness and containing such things as objectivity, intellectual honesty and caution in drawing conclusions and making decisions; and (iii) commitment to particular scientific beliefs such as loyalty to truth, cause and effect relationships, etc.

Such analyses clearly indicate the multidimensional nature of 'scientific attitudes', in Gardner's sense (1975b), within the general construct of attitudes related to science. Nevertheless numerous instruments developed to measure 'scientific attitudes', including Test of Science Related Attitudes, TOSRA (Fraser, 1981), have ignored multidimensionality at this level. Gardner (1975a) was critical of such an approach stating '... it is conceptually muddy in the extreme to pretend that there is a single unidimensional trait called 'the scientific attitude' which can somehow be measured by adding up scepticism plus faith plus precision plus humility ...'.

This paper describes the development of an instrument to measure students' 'scientific attitudes' along four dimensions. These four dimensions have been derived from a set of statements elaborating the attitudinal aim of the New South Wales Science Syllabus, Years 7-10, 1975. Admittedly a conceptual analysis of the term

'scientific attitude' may have produced a different and perhaps more valid set of dimensions. However, if an instrument is to be used in the evaluation of a particular science syllabus, then it must be congruent with the aims statement of that syllabus. This is a continual dilemma in attempting to evaluate the affective impact of a science curriculum. All other things being equal, well known, valid and reliable instruments are to be preferred. As Munby (1983) has pointed out: 'The field of measuring attitudes is replete with instruments, but ... these instruments are used in a rather cavalier fashion without heed to their reliability and validity'. One hesitates then to add yet another, perhaps doubtful, instrument to the collection. However when no existing instrument is completely congruent with those objectives of a syllabus or curriculum which one wishes to evaluate, there is little option but to develop a suitable set of scales, with due regard to their validity and reliability.

ATTITUDINAL AIM OF NEW SOUTH WALES SCIENCE SYLLABUS

The New South Wales Secondary Schools Board (1973) in its science syllabus for Years 7-10, includes as its attitudinal aim, 'to develop a belief in the value of' five different aspects of scientific endeavour. One of these aspects is 'thinking critically in an unbiased and open-minded manner'. In an expansion of this statement, the syllabus states:

The students who develop a belief in openmindedness and critical thought will recognise the need to:

- . demand evidence in support of claims
- . believe in cause-effect relationships
- . consider new or additional evidence relating to currently held ideas
- . consider whatever data is accessible when formulating decisions
- . examine as many sources of information as possible when searching for explanations
- . suspend judgement when there is insufficient evidence to make a decision
- . be honest in reporting observations.

THE PRESENT STUDY

The objective of the present research was to develop an instrument which:

- . could be used for evaluating this curriculum but not for pupil assessment;
- . contained a number of scales established empirically, which relate to each of the components of scientific attitude as explicated in the science syllabus;
- . would be subjected to appropriate statistical analysis in an attempt to substantiate reliability and validity.

The instrument, Science Opinion Survey, SOS, was developed by the first author as part requirement for an M.A. degree (Jones, 1981). It was field tested further in a study conducted by the second author with the assistance of post-graduate students enrolled in a science education seminar.

PREPARATION OF THE INSTRUMENT

Gardner (1975a) suggests techniques for developing scales for attitude measuring instruments. One involves submitting a jumbled collection of items to a panel of judges and asking them to identify to which construct each item relates. Another suggested procedure is to subject item responses to factor analysis and use this information to form separate scales. Both procedures were used in the development of SOS as described below.

Item Writing. Statements for a Likert type instrument were written for each of the seven components of scientific attitude as specified in the syllabus. However it was found too difficult to construct items for the syllabus statement 'consider whatever data is accessible when formulating decisions' that were different from items for the statement 'examine as many sources of information as possible when searching for explanations'. Consequently only one scale was developed for these two syllabus statements, reducing the number of scales to six, hereafter referred to as: Concern for Evidence; Causation; New Evidence; Sources of Information; Suspension of Judgement; Honesty.

Judging Panel. Equal numbers of positive and negative items were written for each of these six scales and then all items were scrambled. The scrambled items were given to eight judges, mainly science teachers, who were asked to place each item in the scale they thought appropriate and to say whether it was a positive or negative item. Good agreement was found between the judges on the placement of most items, although some rewriting and replacement of items was necessary.

Informal Trial. An informal trial of the instrument was conducted with the twenty-five Year 10 pupils in a country central school where the first author was then teaching. Problems of comprehension were identified and items amended to overcome confusion.

Trial of the Instrument. The final trial version of the instrument consisted of the six scales identified above. Each scale contained ten items, five positive and five negative. The items were scrambled. The instrument was administered to the entire Year 10 population at a Sydney co-educational high school, in a suburb of mid socio-economic status, and yielded 209 usable responses.

STATISTICAL ANALYSIS

The students' responses were computer analysed and the following statistics generated: scale means and standard deviations; correlations between each item and each scale; interscale correlations and Cronbach's alpha for each scale. Items which did not correlate well with the scale to which they had been allocated and items which produced only a narrow range of responses were rejected. It was found that the interscale correlations among the three scales Concern for Evidence, Suspension of Judgement, and Sources of Information were very high. Also the judges had misplaced items between these scales. Therefore the three scales were combined and subsequently treated as one common scale, named Scepticism. The twelve best items from the original thirty, on the basis of item statistics, were selected to comprise this scale.

Item rejection also led to the three other scales in the instrument being reduced to eight items, four positively and four negatively stated. Table 1 provides data on the characteristics of the surviving four scales, obtained from the trial sample and also from a larger replication sample described later.

TABLE 1

S O S SCALE CHARACTERISTICS

	S O S Scale							
	New Evidence		Causation		Honesty		Scepticism	
Number of items	8		8		8		12	
Sample n	209 ^b	939 ^c	209	939	209	939	209	939
Mean ^a	64	64	61	59	58	59	62	64
Standard Deviation ^a	15	11	18	14	15	13	15	11
Cronbach's alpha	0.63	0.50	0.70	0.67	0.64	0.66	0.64	0.67

- a. Given as percentages on a 0-4 scale
- b. Jones' trial sample
- c. Butts' replication sample

Factor Analysis. A factor analysis was carried out on the responses to all sixty items in the instrument. Four interpretable factors were identified in a five factor solution

involving Varimax rotation. One factor accounted for 45.4 per cent of the variance. All the items associated with this factor which had survived item analysis, were from the Scepticism scale. This further justifies the combination of the three scales into the one Scepticism scale. Factor 2 accounted for 18.0 per cent of the variance. All of the surviving items from the Honesty scale, and little else, loaded highly ($>.2$) on this factor. The third factor accounted for 14.8 per cent of the variance. Only items from the Causation scale loaded highly on this factor. The fourth factor accounted for 12.4 per cent of the variance. The items which loaded highest on this factor were from the New Evidence scale. However some items from other scales loaded on this factor, but not as highly. The fifth factor, which accounted for 9.3 per cent of the variance, contained only items which had been eliminated after item analysis because they had unsatisfactory statistics. While this analysis provides evidence for the multidimensionality of the construct 'scientific attitude', many items did load on more than one factor and the four scales were found to be related. Table 2 shows interscale correlations for both the trial sample and the later replication sample.

TABLE 2

S O S INTERSCALE CORRELATIONS

Sample n	Causation		Honesty		Scepticism	
	209	939	209	939	209	939
New evidence	0.19	0.09	0.45	0.30	0.50	0.39
Causation			0.41	0.18	0.47	0.19
Honesty					0.55	0.45

Discriminant Validity. Ideally, scores on the four scales of the Science Opinion Survey should correlate highly with scores on other instruments designed to measure similar attributes but have negligible or low correlations with measures of distinctly different attributes. A correlation of 0.84 was found between scores on the Scepticism scale of SOS and scores on an appropriate set of items from the Scientific Attitude Scale of Meyer's 'A Test of Interests' (1969). However correlations between SOS scales and interest scales in Meyer's test were low (0.10 to 0.22). Furthermore, correlations with achievement on a half yearly examination paper were reasonably low (0.13 to 0.42). Taken together these data provide evidence for the discriminant validity of the scales of the instrument developed.

Sample Items. Two sample items from each of the four scales of SOS are given in Box 1.

BOX 1

S O S Sample Items

NEW EVIDENCE

- I wouldn't laugh at a way out idea if there was some proof for it.
- I would not listen to someone who said she could prove that man can go back in time.

CAUSATION

- It is silly to think that anything could happen without some basic cause or explanation.
- Some people are unlucky and this is beyond human control.

HONESTY

- When an experiment does not work properly I still report what I have seen.
- Sometimes you need to change the results of your experiments a bit to get them to work out right.

SCEPTICISM

- I like to make sure that I know all the facts before I make up my mind.
- One experiment is usually enough to base your conclusions on.

FURTHER VALIDATION

While the first author had developed, with the help of item analysis, a 36 item instrument to measure scientific attitude along four pre-defined dimensions, this abbreviated instrument had not been used as such with a student population. Only the 60 item instrument from which the final set of scales was derived had actually been responded to by students. The second author therefore conducted a further field test of the instrument with a larger population in nine different Sydney high schools. Although only a convenience sample, this group contained single sex and co-educational high schools, some of them government schools and some non-government schools. The schools were representative of a range of socio-economic status. Again Year 10 pupils responded to the survey. The data obtained from a total of 939 responses were analysed as before. Relevant data are also recorded in Tables 1 and 2.

Factor Analysis. A five factor solution (Varimax rotation) was performed as before. All eight items from the Causation scale had their highest factor loadings (0.21 to 0.67) on Factor 1. No other item loaded highly (>0.2) on this factor. This, together with the low correlations between this scale and the other three scales in the instrument, confirm that these items are measuring a unique construct. It is interesting to note that Jones' original Factor I was allocated to the Scepticism scale, a result which may be attributable to the different nature of the populations in the two surveys conducted. The second factor had five items from the New Evidence scale loading highly on it, although some items from all other scales also loaded highly (>0.2) on this factor. This scale also has the lowest reliability of the four scales in the instrument. All items from the Honesty scale load highly on Factor 3, although some items from the Scepticism scale also load highly on this factor as well. Factor 4 appears to be associated with the Scepticism scale, seven of that scale's items loading highly on it. It is of interest that four of the remaining five items of this scale have their highest loadings (0.25 to 0.44) on Factor 5, while only two other items have loadings above 0.2 on this factor. The four items from the Scepticism scale which load highly on Factor 5 are closely related conceptually, a reminder that this scale was obtained by collapsing what were initially three separate scales.

CONCLUSION

A new instrument has been developed for measuring students' scientific attitudes along four dimensions, concern for new evidence relating to currently held ideas, belief in causation, honesty in reporting and scepticism (involving suspension of judgement, concern for evidence and use of many sources of information). From a field test with a sample of over nine hundred Year 10 students from nine diverse Sydney high schools, there is evidence to justify treating scores on the four scales separately, rather than combining them to provide a single 'scientific attitude' score.

It is recommended that the instrument be used in curriculum evaluation as a means of identifying those attitudinal objectives of the relevant science syllabus which may not be being achieved to the satisfaction of the school or science teacher(s) concerned. By treating these four scales independently it will be possible to identify those aspects of the affective domain needing special attention. Teachers may then develop appropriate teaching strategies for overcoming the deficiencies which they perceive to be present in their science curriculum or in its implementation.

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COGNITIVE PREFERENCES AND CHEMISTRY ACHIEVEMENT

Campbell J. McRobbie

INTRODUCTION

The cognitive preference construct was developed by Heath (1964) in the context of the curriculum movement of the 1960s. It was developed to evaluate the cognitive styles of learners resulting from a study of the curricula of that era which attempted to influence the students' 'modes of attending to the subject matter of the course' (Heath, 1964, p.241). It was hypothesised that after studying these curricula, students would show higher preferences for concept formation and the understanding of general principles than for rote memorisation of factual information when compared to students studying traditional curricula. This construct was devised to assess these information processing differences in students.

It has been extensively employed in the curriculum evaluation role in which it was developed. The general conclusion from studies comparing the cognitive preferences of students as a result of studying various curricula is that the newer programs have tended to develop information processing preferences consistent with the orientation of those curricula (Mackay, 1971; Tamir, 1975).

The cognitive preference construct has also been shown to be largely independent of general aptitudes (Williams 1975; Mackay, 1971; Theobald, 1977), intellectual development (Blake, 1976), and other cognitive style measures such as field-dependence, field-independence (Blake, 1976; Dekkers & Johnston, 1980), and educational set (Lucas, 1978).

Many studies have been conducted on the patterns of relationships between cognitive preferences and science achievement. For example, Mackay (1971), Heath (1964), Tamir (1975), and Tamir and Yamamoto (1977) have reported significant relationships in physics, biology and lower school science classes. Kempa and Dubé (1973) and McNaught (1982) have reported significant correlations between cognitive preferences and achievement at O-level and matriculation level chemistry respectively. Further, McNaught noted that a higher score on a particular cognitive preference was associated with better performance on the kinds of cognitive tasks implied by that cognitive preference.

These studies have shown that the cognitive preference of the student can be influenced by the program studied and that particular cognitive preferences are

associated with high achievement. Cognitive preferences have not, however, been studied as independent variables in accounting for science learning. For this variable to be seen as a significant factor in influencing learning, it would need to be shown to account for a unique and significant portion of the variance associated with science learning that is not accounted for by other commonly studied variables of educational interest.

This report is part of a larger study (McRobbie, 1982) which investigated the contribution of the cognitive preferences of the student to chemistry learning in the context of general aptitude, initial cognitive structure variables, the cognitive style variable educational set (Siegel & Siegel, 1965) and differing instructional treatments.

A LEARNING MODEL

The learning model which provided the basis for this study characterised learners as possessing the following internal consistencies in cognitive functioning:

- a predisposition to respond to factual or conceptual information;
- a tendency to seek factual or conceptual relationships between the new learning and established ideas in the cognitive structure of the learner and to organise this new learning by relating it to established ideas in the cognitive structure of the student in a way that reflected this relationship.

The effects of these consistencies on learning were postulated as being moderated by:

- the cognitive strategies activated by the characteristics of the instructional treatment conditions; and
- the presence in the initial cognitive structure of the learner of specifically relevant information (factual and conceptual) and the organisational characteristics of that information.

Learners were characterised on a factually set-conceptually set continuum. Their differing predispositions and organising tendencies were seen as leading to differences in their cognitive structures. Factually set learners were seen as more likely to learn in a comparatively rote fashion and to develop a comparatively isolated cognitive structure as a result of these tendencies and the nature of the information to which they responded (Ausubel, 1968, p.102). Similarly, the conceptually set learner was seen as more likely to learn in a comparatively meaningful way leading to a well-integrated cognitive structure.

RESEARCH DESIGN

The sample consisted of 160 students in ten classes in five Brisbane metropolitan high schools. The schools were randomly selected and all Grade 12 chemistry students in each school participated in the study. The study was conducted in the

normal school learning environment to maintain representativeness of the learning situation (Snow, 1974) and ecological validity (Bracht & Glass, 1968). Classes were randomly assigned to the alternate instructional treatments, each treatment being equally represented in each school.

The design of the study is illustrated in Box 1, which shows the schedule for administration of the tests and instructional learning programs. In addition, each student's score on the science subscale of the Australian Scholastic Aptitude Test was obtained from official records as a measure of general aptitude for science learning. This variable is coded ASAT in later discussions.

BOX 1

Administration of Test Instruments and Instructional Materials

Initial Tests

Period 1	Initial cognitive organisation test
Period 2	Cognitive preference test followed by educational set test
Period 3	Initial knowledge test
	*Normal class work

Instructional Treatments

Approximately 3-4 weeks, or 14 periods	Program I - conceptual program or Program II - Factual program
	*Normal class work
Posttest - Period 1	Posttest cognitive organisation (not reported here)
Period 2	Posttest knowledge
	* Normal class work

Instructional Treatment

Approximately 1 week, or 4 periods	Program III - final program (all students)
	*Normal class work

Final Test

Period 1	Final knowledge test
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* Normal class work involved approximately one week of unrelated chemistry taught by the class teacher.

Test of Cognitive Organisation : The technique used to assess the cognitive organisation of the student was an adaptation of the word association technique. Adaptation was required to accommodate strong criticism of the technique by, for example, Stewart (1979) and Gunstone (1980).

The major criticism lay in the fact that this technique did not ascertain the nature of the propositional link connecting the stimulus and response words. Accordingly, students with very different and even incorrect cognitive structures could therefore be characterised by the same indices. Further, Pines & Leith (1982) note that 'all scientific meaning is propositional'. Therefore in this study, after the response words/phrases were made to each of the six stimulus words, students were asked to write a sentence linking the stimulus and response words to show the nature of the propositional link between them. Gunstone (1980) used a similar procedure.

The linking propositions were then categorised as factually or conceptually oriented. Factual statements were seen as those probably requiring only rote learning and were often specific examples. Generalisations and principles which would probably require understanding to comprehend their meaning were classified as conceptual.

Test/retest reliability was 0.89 for factual statements and 0.85 for conceptual statements ($N = 35$). The coefficient of interjudge agreement (Cohen, 1960) between the researcher and one other science educator who classified a random sample of the response was 0.78. Interviews with selected students further confirmed the validity of the categorisations. Additional summary statistics are reported in Table 1.

Knowledge Tests : Multiple choice tests for knowledge were administered at three points in the study. The initial knowledge test assessed the students' knowledge of factual and conceptual information relevant to the instructional programs or to which the new learning could be related. The knowledge acquired as a result of studying the alternative instructional programs was assessed at the post stage and that at the final stage after each student had studied the same final instructional program.

Items in these tests were assessed as factual or conceptual, depending on the cognitive operations inferred as required to answer particular items. Items assessing factual knowledge were those requiring only recall or recognition of information previously presented in the instructional programs or expected to have been presented in the student's previous studies. Conceptual items were those requiring application of the principles and concepts developed in the instructional program (or expected to have been previously developed) to new chemical systems. Each test contained an

TABLE 1

Summary Data For Test Instruments

VARIABLE AND CODE		MEAN	S.D.	CRONBACH αC	NUMBER OF ITEMS
<u>Cognitive Organisation</u>					
factual relationships	1ORF	17.6	5.7	-	-
conceptual relationships	1ORC	4.4	3.3	-	-
<u>Cognitive Preference</u>					
MQ dimension	CPMQ	1.6	4.5	0.41	12
AP dimension	CPAP	1.2	5.3	0.55	12
<u>Educational Set</u>	EDST	1.3	6.8	0.58	12
<u>Initial Knowledge</u>					
total	1KNT	13.0	4.2	0.73	24
factual	1KNF	7.0	2.4	0.62	12
conceptual	1KNC	6.0	2.4	0.61	12
<u>Post-stage Knowledge</u>					
total	PKNT	13.8	4.2	0.67	28
factual	PKNF	6.8	2.2	0.50	14
conceptual	PKNC	6.9	2.6	0.57	14
<u>Final Stage Knowledge</u>					
total	FKNT	6.4	2.8	0.60	16
factual	FKNF	2.9	1.6	0.40	8
conceptual	FKNC	3.6	1.7	0.43	8

equal number of factual and conceptual items. Each test provided three scores - a factual item score, a conceptual item score and a total score for all items in the test instrument. Summary statistics for the knowledge tests are reported in Table 1.

Cognitive Style Tests

Educational Set : An educational set test was employed to ascertain the pre-disposition of the student to respond to factual or conceptual information. Each item in this test consists of three optional statements which are classified in relative terms as factual, intermediate and conceptual in orientation. Students select that optional statement which would interest them most to learn and that which would interest them least. For examples of test items, see Siegel & Siegel (1965).

By scoring +1 for each selection of a conceptual statement as most liked to learn or a factual statement as least liked to learn and -1 for the reverse situation (no marks for the selection of the intermediate statement), students obtained a score on the factually set-conceptually set continuum. With 12 items in the test, the maximum score was thus 24.

The test items were constructed such that optional statements within an item differed on conceptual level but not on interest level, difficulty level or relevance to the course of study as determined by student ratings of the optional statements on these dimensions. The test/retest reliability was 0.86 ($N = 35$). Further summary statistics for this test instrument are reported in Table 1.

Cognitive Preference : A cognitive preference test was employed to ascertain the tendency of the student to seek factual or conceptual relationships between the new learning and established ideas in cognitive structure.

An example of a typical cognitive preference test item is

ITEM 1

When silver nitrate solution is added to a solution of sodium chloride, a curdy white precipitate is formed:

- (a) The reaction between silver nitrate and sodium chloride solutions can best be described by the equation:



- (b) This reaction is the basis for determining the concentration of chloride ions in sea water. (A)
- (c) The differences in the sizes of silver and sodium ions might account for the different solubilities of silver chloride and sodium chloride. (Q)
- (d) The fact that a silver chloride precipitate is obtained means that the solution is fully saturated with respect to silver chloride. (P)

Students are asked to indicate the optional statements which they see as most/least related to the chemistry in the stem of the question. Each preference option is assumed to show a particular type of relationship with the information given in the item stem and the interest is in the type of relationship rather than in the particular option itself (Mackay, 1971). This allows inferences to be drawn about how students will go about extending their learning in relating new information to established ideas in their cognitive structure. That is, the cognitive preference of the student is considered to reflect the process of organising new learning into the learner's existing cognitive structure.

The four cognitive preferences relationships identified by Heath (1964) were used in this study. They are identified in the example above and elaborated below.

- Memory/Recall (M) : A preference for remembering a specific fact, term, or formula associated with the given information. Acceptance of scientific information for its own sake without regard to implications, applications, or limitations.
- Principles (P) : A preference for identifying the fundamental principles underlying the given information.
- Application (A) : A preference for learning information emphasising its practical application to real life situations.
- Questioning (Q) : A preference for critically questioning or challenging the information given in extending its completeness, validity, or implications.

In this study, the cognitive preference test items contained triads of optional statements which were selected so as to differ on conceptual level but not on interest level as determined by student ratings on the optional statements on these dimensions. The 12-item test contained equal numbers of each triad combination of the four cognitive preference modes. Factor analysis of the results for this test showed that the individual preferences could be more parsimoniously represented by two approximately orthogonal dimensions. These dimensions gave two scores for each student on this test - the M-Q dimension and the A-P dimension. A preference for A over P and M over Q on these dimensions was seen as representing a set in the factual direction and vice versa for the conceptual direction. Summary statistics for scores on these dimensions are reported in Table I. Test/retest reliability ($N = 35$) on these dimensions was 0.88 and 0.87 respectively.

Instructional Treatments : The alternate instructional treatments were individualised learning programs involving a study of the electrochemical series and the Nernst equation. They were designed to reflect probable information processing styles of the factually set and conceptually set learner discussed earlier. Three science educators confirmed the validity of these instructional treatments as reflecting the postulated learning styles.

In the instructional treatment reflecting the probable information processing style of the conceptually set learner, for example, the electrochemical series was developed from a study of (half) reactions in a laboratory oriented inquiry approach with the concepts and principles developed being related to existing ideas in the learner's cognitive structure. On the other hand, the instructional treatment reflecting the information processing approach of the factually set learner simply presented the electrochemical series and then discussed examples of its application. The same laboratory activities as in the previous program were conducted but in a manner unrelated to the other sections of the program.

The final instructional treatment was designed to extend the knowledge and skills of the earlier instructional treatments to that of electrochemical cells and electrolysis. This instructional treatment assessed the influence on further learning of different cognitive structures that may have been developed as a result of studying the earlier instructional treatments - a transfer retention test (Ausubel, 1968).

ANALYSIS AND RESULTS

The major technique of analysis employed was that of multiple regression. This technique was used to test the null hypothesis that:

- the cognitive preference dimension MG (or AP) does not account for a significant proportion of the knowledge acquired by the learner when the effects of instructional treatments, educational set, cognitive preference dimension AP (or MG) and initial cognitive structure variables are controlled.

This hypothesis was investigated for total, factual, and conceptual knowledge acquisition at the post- and final stages in the design.

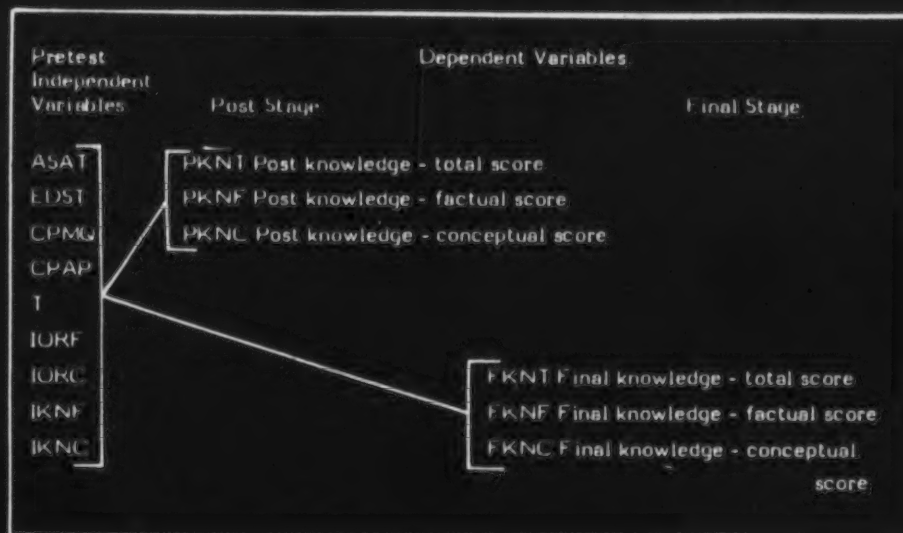
Interactions were first tested for significance and only the significant interactions were retained for testing main effects (Theobald, 1977). The unit of analysis was the individual student. It is therefore prudent to acknowledge the possibility of confounding effect arising as the class is the experimental unit and the individual the statistical unit of analysis (Keppel, 1973). The results of this study should be considered with this in mind. On the other hand, such effects would have been expected to be minimised due to the individualised nature of the learning programs (Cronbach & Snow, 1977) and the fact that the treatment groups were random in effect (Lord, 1963) and equally represented in each school (Kerlinger, 1973). Further, the use of the individual as the unit of analysis is consistent with a study of individual differences.

Table 2 shows the organisation of the multiple regression analyses and the dependent and independent variables involved.

The final regression models for the six analyses in Table 2 showed that cognitive preference dimensions were a significant predictor of achievement in only two instances. The cognitive preference dimension AP was a significant predictor variable for dependent variables PKNC and FKNC. Only these two regressions are reported here, full details of all regressions being available in McKobbie (1982).

TABLE 2

Organisation of the Multiple Regression Analyses
Showing Dependent and Independent Variables



For dependent variable PKNC, the final regression model accounted for 38 per cent of the variance which is a statistically significant and also an educationally significant percentage of variance. The overall regression equation in raw score form was:

$$Y = 1.22 + 0.14ASAT + 0.23IKNC - 0.07CPAP - 0.27(T \times IKNC) + 0.06(T \times ASAT) \quad (1)$$

In standard score form this equation becomes:

$$Z = 0.43ASAT + 0.21IKNC - 0.14CPAP - 0.68(T \times IKNC) + 0.77(T \times ASAT) \quad (2)$$

Learners who scored high on the CPAP variable showed a preference for A over P. In the learning model for this study such learners were described as factually set and were predicted to have lower achievement than learners with low scores - a conceptual set - on this variable. This prediction is consistent with the regression equations above.

The standard score form of the equation shows, however, that this is probably not an educationally significant effect. A one standard score difference in cognitive preference score on dimension A-P would produce only a -.14 standard score change in dependent variable PKNC. In most instances, a change of about 0.30 would be classed as an educationally significant effect.

For dependent variable FKNC, the final regression model accounted for 12 per cent of the variance which was a statistically significant [$F = 3.08$; $p < 0.05$ ($df = 5, 154$) $F = 2.27$] and an educationally significant percentage of the variance. The lower variance accounted for could be due to the comparative 'remoteness' of the specifically relevant independent variables or an indication that other factors not included in the original regression model are significant predictors of achievement at this stage.

The overall regression equation in raw score form was:

$$Y = 0.51 + 0.05ASAT + 0.05EDST - 0.19CPAP - 0.02(CPAP \times IKNC) - 0.01(CPAP \times IORF) \quad (3)$$

The effects of the CPAP variable are entwined in a complex interaction with the IKNC and IORF variables.

The effect of these interactions can be examined separately by, for example, considering the CPAP $\times$ IKNC interaction for mean scores on the IORF variable and vice versa. This examination shows that an educationally significant difference in the dependent variable of about 0.30 would occur for students above the 40th percentile on IKNC scores and the 65th percentile on IORF scores. This effect is considered educationally significant. Further, the significance of the cognitive preference dimension A-P as an independent variable accounting for chemistry achievement as reported in this study is consistent with other correlational studies on this relationship discussed in the introduction. In particular, Kempa and Dube (1973) showed that low scores on the cognitive preference dimensions M-Q and A-P were significantly correlated with high achievement in O-level chemistry. McNaught (1982) reported that, as in this study, low scores on the dimension A-P were associated with conceptual achievement in chemistry at matriculation level but not with overall achievement.

CONCLUDING COMMENTS

This study has shown that the cognitive preference dimension A-P is a statistically and educationally significant variable in accounting for chemistry learning at matriculation level.

Considerable effort has been expended in recent times in investigating strategies that students apply in learning and in modifying or developing strategies that will assist students to learn (Novak, 1980; Brown et al., 1981). A number of authors have suggested that particular cognitive styles should be developed in students to assist

their learning (Hunt, 1975; Messick, 1979). Further, as reported earlier, cognitive preferences have been shown to be influenced by the instructional program studies.

It is contended, therefore, that the development of conceptually oriented cognitive preferences should be seen as an important objective for science education and that curricula should continue to be evaluated for the cognitive preference orientations they are developing in students. Further, while the curriculum evaluation literature relating to cognitive preference studies shows that modern inquiry programs tend to develop such cognitive preferences, further research is required into ways of more deliberately influencing these information processing styles.

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SCIENCE TEACHING, ATTITUDE TO HEALTH AND AWARENESS OF HEALTH ISSUES

Max Maddock

This paper reports the results of the latest of a series of studies carried out by the author between 1977 and 1982 which attempt to evaluate attitudinal objectives stated by the New South Wales secondary science syllabus. This study evaluates the attainment of the objective

To develop a belief in the value of community and personal health.

(Secondary Schools Board, 1980)

Since the 1960s there has been an increasing emphasis on attitudinal objectives in the teaching of science and the New South Wales junior science syllabus has five such objectives, related to thinking critically, use of science to solve problems, persistence with tasks, personal and community health and wise management of natural resources (Secondary Schools Board, 1980).

One of the underlying assumptions behind such objectives is that information provided in school science courses can contribute to attitude development. On page 11 of the draft syllabus, under a heading 'Staying Healthy', the syllabus states:

Commencing with an investigation of those factors which contribute to poor health in man[kind], content should be chosen to extend each student's knowledge and understanding of

- the body systems and how they function
 - the conditions necessary for proper functioning of body systems
 - the effects of stress, drugs, environmental pollutants and poor nutrition have on these systems
 - the attitudes and habits which contribute to healthy living
- so that wiser decisions can be made in relation to the development of sound health practices.

Similarly, on page 9 of the syllabus, environmentally oriented content concerning competition for resources, wastes and disposal, man-made changes and effects on the environment is specified so that a 'more complete appreciation of the effects of technology on the environment is developed'. Three of the previous studies, reported in Maddock (1978, 1979, 1982a,b) have shown that as far as the attitude to conservation objective stated in the syllabus is concerned, no mean changes in attitude were found to occur from when the pupils entered high school in grade 7 to

when they left at grade 10 or 11, and the 1981 study (Maddock, 1982a) showed that this is despite a highly significant increase in awareness about environmental issues. Correlations of attitude with awareness, achievement on classroom science tests and IQ showed attitude to be independent of these other variables. Two studies (Maddock, 1979, 1982b) showed no development in attitude to critical thinking over grades 7-10.

All of these studies have employed a method of attitude scaling, first developed by the author in studies in Papua New Guinea (Maddock, 1973), which differs from the traditional techniques of attitude scaling.

The study reported here was designed as a pilot study to

- develop scales for measuring attitude towards community and personal health and for measuring awareness of (or knowledge of) facts concerning health issues;
- use the scales to investigate grade level effect on attitude, and awareness;
- investigate relationships among attitude to health, awareness of health issues, classroom science achievement, and IQ.

The study was carried out on a sample of 636 high school students in grades 7-11 in eight high schools in the Hunter Valley area of New South Wales, the same area where the author carried out the previous studies (Maddock, 1978, 1979, 1982a,b). The sample was representative of the Hunter Valley population; it contained both urban and rural schools and a range of classes from 'low ability' to 'high ability' (based on the streaming system used by the schools). The scales were developed, administered and analysed with the assistance of the 1982 Dip.Ed. Science Curriculum and Method class at the University of Newcastle.

THE ATTITUDE SCALE

The Attitude to Community and Personal Health Scale (CPH) consists of 24 items concerned with specific situations related to health. Each item gives three choices giving possible specific reactions in such a situation, one reflecting a positive attitude (scored 3), one a negative attitude (scored 1) and one a non-committed, or intermediate attitude (scored 2). Respondents are asked to select which is closest to what they consider their own reactions would be under the same circumstances. The scale could be described as drawing on a 'behavioural intention' aspect of attitude, as defined by Fishbein and Ajzen (1975) and Triandis (1975). The situations used in the items have characteristics related to Jordan's (1974) upper levels of specific, real-life behaviour in his six category system for attitude scales.

Examples of items from the scale are:

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- If you are at a self-serve snack bar and have a choice of the following three, which would you select?

1 A chicken leg, piece of tomato, brown bread and butter, glass of orange juice. (score 3)

2 A hamburger with lettuce and tomato, piece of cake, bar of chocolate, cup of coffee. (score 2)

3 A hot pie and sauce, piece of cream cake, bar of chocolate, bottle of coca cola or orangeade. (score 1)

• A friend of yours attends a party and has a few too many alcoholic drinks. At the end of the party when guests are leaving, he wants to drive his car home. What should be done?

1 He should be given lots of black coffee and then after a rest be allowed to drive home. (score 1)

2 You are undecided what should be done. (score 2)

3 It should be insisted that he calls a cab, or travels in the car with some other person who has not been drinking, or stays the night. (score 3)

The items used situations concerning personal health such as diet, hygiene and basic health precautions and concerning public health such as vaccination, alcohol, cigarette smoking, public hygiene, and use of weedkillers in public places.

THE AWARENESS SCALE

The Health Awareness Scale (HA) is a 28 item multiple-choice scale with a right-wrong scoring system aimed at knowledge or awareness of facts concerning personal and public health issues, such as the latest method for snakebite treatment, legal limit for blood alcohol for driving, disease caused by vitamin deficiency, sources of protein, a process for killing bacteria and cause of food poisoning.

An example of an item from this scale is

• Why is rubella (German measles) considered to be a serious disease in the community?

1. It is an almost certain cause of death.

2. It cannot be cured by treatment.

3. It can cause serious defects in unborn children.

4. Vaccination will not prevent the disease.

SCALE STATISTICS

Reliability and internal consistency

Both scales produced a coefficient alpha which satisfied Nunnally's (1969) criterion for usefulness for research. The CPH scale alpha was 0.77 and the HA alpha was 0.80. In the CPH scale, only two items produced item-total correlation of less than 0.2, with 18 of the 24 items producing a correlation above 0.35. In the HA scale, only two items gave correlations of less than 0.2 and 21 of the 28 items gave correlations of above 0.35.

Score Range

The attitude (CPH) scale had a maximum possible score of 72 and a minimum possible of 24. The mean score for the population was 59.3 (standard deviation 6.35), which is towards the positive end of the continuum, with the distribution slightly skewed in a positive direction. The scores ranged from 72 (obtained by 1 per cent) down to 36 (also obtained by 1 per cent). Four per cent scored 70 scale points or higher, while 3 per cent scored less than 40.

For the awareness scale (HA), the population mean was 16.9 (standard deviation 4.81 in a possible score range of 28 to 0), with the scores skewed very slightly towards the positive end of the scale. No subject scored the maximum, but 2 per cent scored 26 or more, and nobody scored zero, although 1 per cent scored only 3 points.

Grade level effects

The data for each scale were subjected to a one-way analysis of variance to determine whether grade level was a factor affecting the scores.

Attitude was found to decline progressively from grade 7 to grade 11, the extent of the decline being from a mean of 62.2 (out of a maximum possible of 72) to 55.6 in grade 11, or 1.05 standard deviations. The decline from grades 9-10 to grade 11 was 0.57 of a standard deviation. An epsilon of 0.24 (Cohen, 1965) indicates that about 6 per cent of variance is associated with grade level. Details of the analysis of variance may be obtained from the author.

The grade level effect in the case of the HA scale was also very highly significant but in contrast to the effect for attitude a steady increase in awareness was found with increasing grade level, the difference between the grade 7 mean of 13.5 and the grade 11 mean of 21.8 representing an increase of 1.7 standard deviations. The F value was 31.37, the epsilon of 0.43 indicating that 19 per cent of variance is associated with grade level.

RELATIONSHIP AMONG VARIABLES

In addition to scores on the CPH and HA scales, results were obtained on science achievement tests, set on work being taught at the time, for 15 separate science classes, and IQ scores were obtained from the pupil record cards. These results were correlated to investigate relationships among the variables.

Correlations between the attitude scores and scores on science achievement tests did not provide any evidence of significant positive relationship. In the case of CPH 11 of the 15 classes yielded negative correlations. Six classes displayed close to zero

correlation. Coefficient alphas for the achievement tests varied, but eight of them provided 0.7 or higher, and only two gave an alpha below .5. To account for these variations in reliability, corrections for attenuation were made, and the correlations obtained are summarized in Table 1.

TABLE 1
Correlation Between CPH and Science
Achievement Tests 1982

Grade	Class *	Correlation	Correlation Corrected for Attenuation
7	1	-.16	-.23
8	4	-.48	-.60
9	1	.09	.13
10	1	-.03	-.04
9	3	-.19	-.35
8	2	.22	.40
9	4	.30	.39
11	Chemistry	-.08	-.12
7	1	-.30	-.55
10	Ungraded	-.41	-.52
10	Ungraded	.22	.23
8	2	-.04	-.05
7	5	-.30	-.39
9	3	-.13	-.18
9	2	-.04	-.06

* Numbers in this column indicate relative ability grouping of class in graded system.

The correlation between CPH and FIA was -.03, consistent with the lack of relationship found between attitude and awareness in the environmental conservation study (Maddock, 1981). Correlation between CPH and IQ was also of zero order (-.02), as compared with 0.13 correlation found in 1981 between attitude to conservation and IQ (Maddock, 1981). On the other hand, correlation between the awareness scores and IQ was a significantly positive .37, compared with 0.60 obtained between awareness of conservation issues and IQ in the 1981 study (Maddock, 1981).

DISCUSSION OF RESULTS

The population mean of 16.9 for the HA scale represents 60 per cent in the 0-28 score range. In relative terms the population may be considered to be better informed about the issues on health awareness tested than the 1981 population was about the conservation issues sampled in the awareness of conservation issues test, where the population mean of 14.2 represented 36 per cent (Maddock, 1982a). Unlike the situation for conservation, where evidence suggests that more knowledge concerning the environment is obtained from sources outside rather than inside the school (Eyles, 1978), the author considers it probable that a significant degree of the awareness of health issues in Hunter Valley schools does come from school courses. Over a period of eight years, the author has observed good science units on diet, disease, drugs, and related health hazards much more closely related to social issues than any conservation-related unit observed.

Although the population mean for the CPH scale was somewhat towards the positive end of the attitude continuum, the highly significant decline of 1.05 standard deviations in mean score from grade 7 to grade 11 strongly indicates that the school program, with its strong component of health-related information in the science program, is not resulting in positive attitude formation for a significant number of pupils. This contrasts with the findings of the previous studies with critical thinking and conservation (Maddock, 1978, 1979, 1982a,b) where attitude remained stable over grades.

There are many other variables at work affecting attitudes, both within and outside the school system, and these studies have not attempted to identify these. In view of the importance of health to the individual and the community and assuming that attitude does relate in some way to behaviour, these results give reason for concern. Although pupils may be extending their 'knowledge and understanding of the attitudes and habits which contribute to healthy living' (Secondary Schools Board, 1980) there is reason to doubt that this will result in their making wiser decisions in relation to the development of sound health practices.

The correlational studies show that attitude scores are independent of awareness, achievement on classroom science tests (most of which are tests of recall of scientific information or to a minor degree understanding of scientific principles), and IQ, although some degree of positive relationship was found between IQ and awareness. A person with a higher IQ is somewhat more likely to be better informed on health issues than one with a lower IQ, but not necessarily to hold a more positive attitude. A person who does well at science is not necessarily more positive in attitude to health.

Fishbein and Ajzen (1975) claimed that a consensus exists that an informational base is a key factor in attitude formation, with attempts to bring about change invariably involving exposure to new information about some object, behaviour, issue or event (p.387). Unfortunately for curriculum planners and classroom teachers, very few of the findings from research into attitudes provide a useful foundation for curriculum decisions or pedagogy. Johnstone and Reid (1981) stressed the need to relate attitude growth to cognition, stating that pupils will develop attitudes, whether schools emphasize them or not, but warn that they may develop without a satisfactory cognitive base. This study indicates that the attitude becomes more negative as a pupil progresses through school, despite syllabus emphasis on health content. Much more research into attitudes is needed in the school setting to help unravel the factors at work.

The findings also cast further doubt, raised by previous attitude studies (Maddock, 1978, 1979, 1982b), about the Secondary Schools Board (1973) policy which requires the addition of marks for attitudes to those from knowledge and for skills for course overall assessment purposes. The results of this study, taken in conjunction with the other findings suggest that if attitude is to be assessed, scores should not be pooled with other measures, but should be treated as independent measures.

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INSIGHTS INTO STUDENTS' OUTLOOKS ON SCIENCE WITH PERSONAL CONSTRUCTS

Keith Stead

The current educational research climate emphasises the 'perspective of the personal' (Pope & Shaw, 1981) as is illustrated by Freyberg and Osborne's (1982) concluding comments in their final report of the 'Learning in Science Project' (LISP):

We believe that the Project has isolated a major problem in science teaching and learning - our failure to devise a curriculum for our pupils which takes sufficiently into account their ideas about the world and their meanings for words [emphasis added].

Such a concern for, and an appreciation of, the learner's perspective has seen the awakening of interest by educators in Personal Construct Psychology (PCP) (Kelly, 1955) - see Yorke (1978); Pope & Shaw (1981); Pope & Keen (1981).

This paper briefly examines the contribution PCP, and the Repertory Grid technique associated with it, can make to an understanding of why girls and Polynesian students are under-represented in the sciences (see Appendix A).

PERSONAL CONSTRUCT PSYCHOLOGY

Kelly (1970), although primarily concerned with the field of clinical psychology, considered the teacher's role as helping

to design and implement each child's own undertakings [and] ... to be a fully accredited participant in the experimental enterprise she must gain some sense of what is being seen through the child's eyes.

This is, of course, precisely what the interview techniques used in the LISP sought to achieve. According to Kelly, each one of us constructs a mental representational model of the world which defines reality to us. The representational model is conceived by Kelly as a network of constructs which is constantly being revised and modified as we encounter events in life. Each construct is, in essence, a bipolar dimension and provides the basis for prediction.

For example, the use of the construct 'boring-interesting' to order certain classroom experiences allows for more than simple categorisation in that, not only may activity A be categorised as boring and activity B to be categorised as interesting but, by describing A as boring, the student immediately implies a number

of predictions about A - perhaps it will be difficult, involve a lot of writing, or irritating - whereas, activity B will be easy, involve a lot of practical work, and may even be dangerous. Thus, these additional subordinate constructions derive from the original construction 'boring-interesting' as predictions (or 'anticipations') and reflect the articulation between constructs in the students' personal construct system. As individual people develop their own idiosyncratic construct system, the rationale for their behaviour is determined by their systems of constructs for ordering and anticipating events.

It is pertinent for us involved in science education to note Kelly's notion of man the scientist. Both as man the scientist and as scientist the man, the individual is in the business of observation, interpretation, prediction, and control:

Thus, for Kelly, the questioning and exploring, revising and replacing in the light of predictive failure which is symptomatic of scientific theorising, is precisely what a person does in his attempts to anticipate events. (Pope, 1980)

Children, as well as scientists, have beliefs about how things happen and have expectations which enable them to predict future events. (Osborne, 1980)

Kelly presented his theory in a formal fashion by proposing a carefully worded Fundamental Postulate: 'A person's processes are psychologically channelized by the ways in which he anticipates events. (Kelly, 1955)

This seemingly simple postulate, further elaborated by eleven corollaries, very neatly provides a psychological paradigm of human behaviour completely different from that of any other. By considering persons (not rats, machines, or societies) and processes, Kelly does away with the need to invoke special notions such as the subconscious, dynamics, drives, motivation, stimuli, needs, to explain why people do not remain inert.

Like the prototype of the scientist that he is, man seeks prediction. His structured network of pathways leads towards the future so that he may anticipate it. This is the function it serves. Anticipation is both the push and pull of the psychology of personal constructs. (Kelly, 1955)

Thus, we are a form of perpetual motion with the direction of the motion determined by the ways in which events are anticipated. The ways in which we anticipate events are defined by our personal constructs.

THE REPERTORY GRID TECHNIQUE

The problem of determining an individual's personal constructs, and the way in which they are used, led to the development of the Repertory Grid technique (Fransella & Bannister, 1977).

A Repertory Grid is essentially a rectangular matrix made up of a set of stimuli, known as 'elements', usually rated (e.g., on a 1 to 5 scale), but occasionally ranked, across a series of constructs. These constructs represent the identified set of discriminatory dimensions which enable the elements to be compared and contrasted with each other. The completed matrix, in which there is a separate column for each element and a separate row for each construct, with a numerical value in each cell, defines a 'row' grid.

In this investigation, it was anticipated the knowledge of the set of elements and constructs which determine an individual's attitudes, feelings, beliefs, and values (collectively referred to as an individual's 'outlook') to science would lead to insights into understanding why particular student groups (girls and Polynesian students) do not continue with their studies in science.

From eight schools chosen to give a representative coverage of ethnic groupings, (Maori, European, Pacific Island) and types (single sex, co-ed, rural, urban, primary, intermediate, secondary) 20 classes (Form 1 to Form 4 inclusive) were given a series of tests by the investigator (see Stead, 1982, for details). From these classes, 26 students were initially chosen to represent, as closely as possible, each of the school, sex, form, and ethnic variables.

Students were interviewed individually about their responses to each of ten Likert-type statements given with a previously administered science questionnaire. Each interview was audio-taped and later transcribed. The transcriptions were scrutinized and the personal constructs identified listed. The individual lists consisted of between eight and 15 bipolar constructs, some of which were supplied by the investigator where the existence of implicit, unstated constructs were suspected (e.g., 'More for Maori kids/more for Pakeha kids').

The elements consisted of the various school subjects studied by each student; a selection of the student's main hobbies, interests, sports, vocational interests, where known; and occasionally, a stereotype adult role (e.g., 'being a housewife', or 'Doing Dad's job').

Each element was written on a small card, together with an identifying alphabetical character, and the entire set of elements, in random order, was given to the student. A wooden 'rule', one metre in length, with a one-to-five scale clearly marked on it was positioned on the desk in front of the student. This rule had provision for placing each construct pole (also written on a card) and the qualifiers 'very', 'fairly', and 'inbetween' on it.

In random order, each construct was displayed on the rule and the student instructed to place each element card in front of the rating considered to be most appropriate to it. On completing this task for each construct, the student read aloud the identifying character corresponding to each element and rating to enable the investigator to record the students' judgement on a prepared blank response sheet. The administration of the grid was completed by asking the student to suggest any other constructs that could have been used. When these were suggested, construct cards were prepared and added to the grid. The triadic approach suggested originally by Kelly (1955) and often used by others, was found to be too time-consuming and often produced trite or superficial constructs of doubtful utility and so was not adopted here.

The data from each raw grid were analysed with a computer program called INGRID (= individual grid) from Slater's (1977) 'Grid Analysis Package'. Essentially this program provided a principal component analysis of the data presented, among other things, the construct and element loadings on each component listed in descending order with those for the component which accounted for the greatest amount of the total variance first, the component which accounted for the next amount of variance next, and so on. The components were mutually orthogonal and, generally, the first three accounted for at least 75 per cent of the total variance. These loadings provided the co-ordinates for locating the position of each element, and one pole of each construct, in three dimensional space.

In order to provide for greater insight into each student's personal construct system, and to allow the students the opportunity to comment on the analyses, a portable kitset was constructed by the investigator which allowed for a convenient construction of a 'model' of each individual student's personal construct system.

Basically, the kitset contained two sets of small plastic spheres (12mm diameter), each set of a different colour, to represent the set of elements, and the set of construct poles. Each sphere was marked with an appropriate character (an alphabetical character for the elements, and a numerical character for the construct poles) and drilled to accommodate the end of a single length of wire (20SWG). A set of pre-determined lengths of wires, corresponding in length to the possible range of loadings on the third component, were located in one half of the kitset carrying case (along with the plastic spheres). The other half of the carrying case comprised the baseboard made of 'particle-board' and drawn up as a two-dimensional graph to accommodate the loadings on the first and second components. This particle-board base was soft enough to readily allow for holes to be made in it with a needle, and yet firm enough to support the wire lengths each topped with a plastic sphere.

Each student was interviewed individually with 'their' constructed model before them and their responses to it audio-taped. The investigator's initial comment was, 'I've made this model up from what you've told me on previous visits and how you shuffled those bits of cardboard around last time I saw you. But, I'm not sure if this is my model, or is it really yours, so I want you to carefully criticise it'.

Their attention was then directed to the element spheres ('The yellow ones') and the identity of each established with reference to the original completed raw grid response sheet and the explanation given that 'those which are close together might appear to you to be similar to each other in some way, but those which are widely separated might appear to be quite different', and the student was asked to explain why this might, or not, be so. On completing an examination of the elements, attention was drawn to the construct poles (these corresponded to those written on the right-hand side of the grid response sheet) and the discussion continued. This allowed for the verification of previously elicited constructs and the elicitation of those previously unexpressed, as well as the identification of any elements or construct poles anomalously positioned.

INSIGHTS ILLUSTRATED

Leanne was the second of two children in her family, aged 11 years, in Form 1 and with an older brother in Form 3. Her father was a mechanic for a large motor company and her mother worked as an office clerk in the same company. Leanne expressed interest in doing jig-saw puzzles, drawing, and playing netball. She claimed science to be her most difficult subject and languages (Maori and French were taught in one hour 'cultural' periods once per week) to be her best. Leanne hoped to become a hairdresser when she left school. She was an academically able student who related well to her peers and to her teacher.

Table 1 gives the elements and the right-hand poles used in the formation of Leanne's repertory grid. All but three constructs were elicited from Leanne either during the discussion on the Likert statements from the science questionnaire or during the discussion accompanying the grid's development. The three exceptions were:

- . What Mum is not interested in - what Mum is interested in.
- . What Dad is interested in - what Dad is not interested in.
- . What we talk about at home - what we don't talk about at home

These were provided by the investigator in order to explore the degree of student-perceived home influence.

TABLE 1

Leanne's Elements and Constructs Used in the Repertory Grid Analysis

Elements	Constructs*
A Hairdressing job	1 I dislike
B Doing science	2 I find easy to understand
C Working with computers	3 I find enjoyable
D Reading books	4 Is encouraged by my parents
E Studying animals	5 What Mum is not interested in
F Playing netball	6 I know nothing about
G Watching TV	7 What Dad is (might be) interested in
H Doing homework	8 Is unimportant
I Reading comics	9 I think is a girl's thing
J Studying plants	10 What I am not (or won't be) good at
K Doing office work	11 Usually for kids
L Studying insects	12 Don't talk about at home
M Doing maths	
N Doing a science job	
O Drawing	
P Doing jig-saw puzzles	

* Only the right hand poles are provided above but the contrast pole was always identified in the formation of the raw grids with the students, and the orientation of each construct was entirely arbitrary. That is, either pole of each construct could just as easily have been used as the 'emergent' pole

The raw grid was analysed with INGRID and the kitset model depicting the element and construct loadings on the first three principal components simultaneously was presented to Leanne. Graphical representations of these loadings are shown in Figure 1.

The several constructs (1, 2, and 3) and 6 and 10) which correlated highly with each other, and the saliency of elements C ('Working with computers'), O ('Drawing'), and P ('Doing jig-saw puzzles') have influenced the positioning of the first component (41.2 per cent of the total variance). The constructs reflected a composite of an affective dimension ('I like/dislike'; 'I find boring/interesting') and a perceived difficulty dimension ('I find easy/hard to understand'; 'What I am/am not good at').

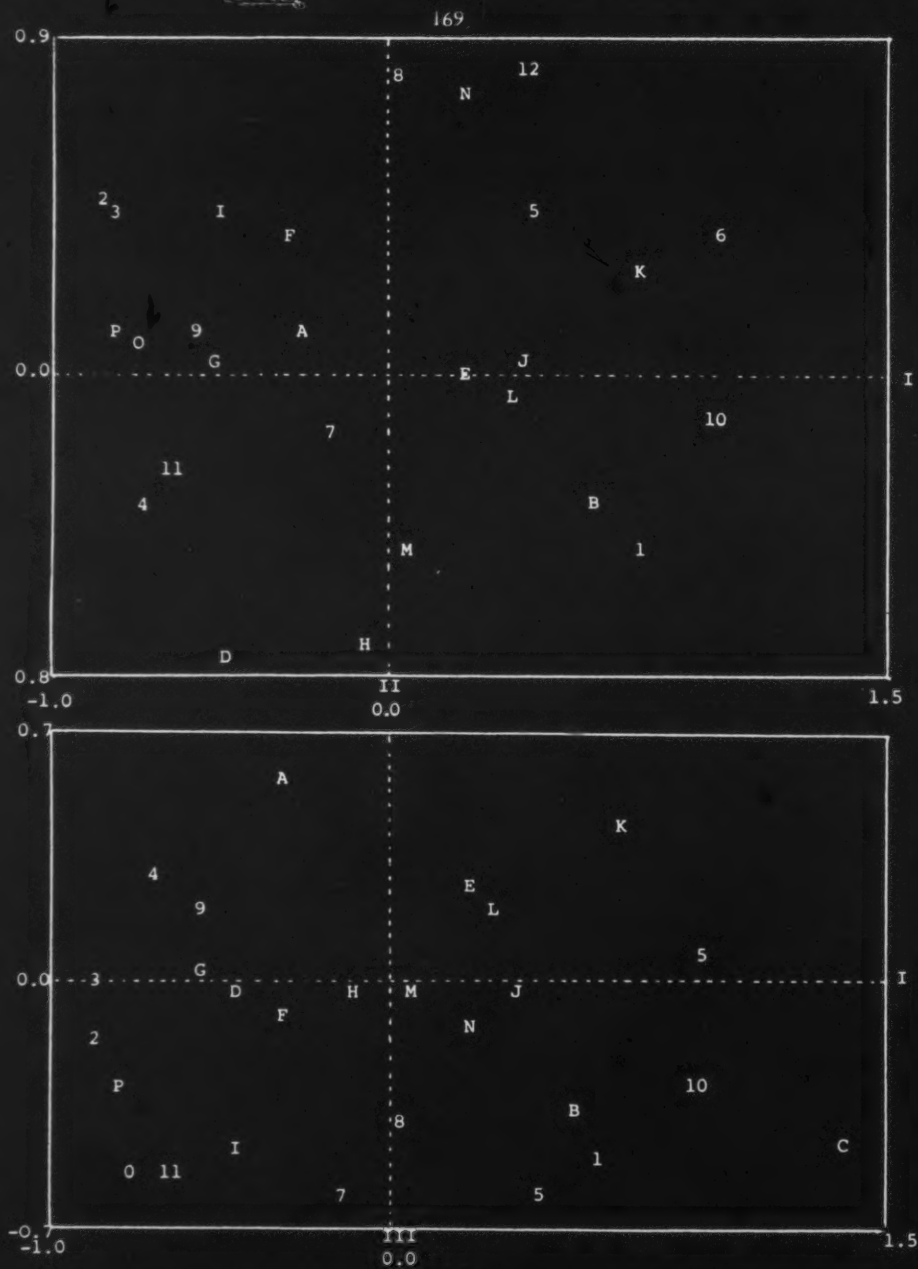


FIGURE 1

The Dispersion of Leanne's Elements and Constructs in Component Space
as Represented by the First Three Components Extracted from
the Raw Grid by INGRID (Slater, 1977)

The second component (19.6 per cent of total variance), with high loadings on it from constructs 8 ('I think is important/unimportant') and 12 ('What we do/don't talk about at home'), a positive loading from element N ('Doing a science job'), and negative loadings from elements D ('Reading a book') and H ('Doing homework'), identified it as being a value dimension. That is, elements with the greatest perceived value are positioned to the bottom of the left-hand graph in Figure 1.

The third component (10.9 per cent of total variance) reflected a 'child/adult' dimension. Constructs 5 ('What Mum is/is not interested in'), 7 ('What Dad is/is not interested in'), 11 ('Usually for kids/adults') and, to a lesser extent, construct 4 ('Is/is not encouraged by my parents'), influenced this component, as did elements A ('Hairdressing job'), K ('Doing an office job'), O ('Drawing') and I ('Reading comics').

The positioning of the science-related elements was such that B ('Doing science') was perceived as not being particularly liked and somewhat difficult. It was something which would (or might) be of interest to 'Dad' but not to 'Mum'. Leanne perceived it as being relatively closely associated with 'Studying animals' (E), 'Doing homework' (H), 'Studying insects' (L), and 'Doing maths' (M). 'Doing a science job' (N) was not perceived as being particularly close to any other element, but was particularly associated with the emergent construct poles of 12 ('What we don't talk about at home') and 8 ('Things that are unimportant').

Leanne I don't like science all that much.

Interviewer Hmm, what sorts of jobs need to have science?

Leanne Um, not quite sure, if you want to be a - if you want to learn more about computers - or something like that. If you, I don't know really.

Interviewer Do you need to know much about science just for everyday living outside the job scene?

Leanne No, not really, I don't think so.

These comments corroborated the positioning of constructs 6 ('I know a lot/nothing about'), particularly with respect to elements B ('Doing science') and C ('Working with computers') - this construct and these elements all load high on the first component and illustrate a possible interpretation of the phenomenon under investigation: a paucity of early science experiences may predispose an individual to develop negative attitudes towards actual, or possible, subsequent like experiences. If girls' sex-role socialisation patterns, rather than boys', lack these early science experiences, then girls will be more at risk than boys in this regard. That is, when events are perceived to be beyond the range of convenience of one's construct system (such as when adequate constructs are not available), anxiety occurs (Kelly, 1955), and this anxiety may be expressed as a 'negative' attitude toward the target experiences.

The following extracts from conversations with Leanne illustrate this possibility. The first came from an earlier interview when the discussion explored her response to watching television science programs.

Interviewer Okay, what is it that you don't like about some of the science programs?

Leanne Boring, usually, to me.

Interviewer And what makes them boring?

Leanne Probably because I don't know much about them.

And the second illustration arose from the discussion concerning the positioning of construct 9 ('I think it is a girl's/boy's thing'):

Interviewer And working with computers, that a boy's thing? So that makes good sense?

Leanne Yeah.

Interviewer And the science is towards that end too, isn't it? Do you think it's slightly more for boys?

Leanne Yeah.

Interviewer Why do you say that? Why do you think science is slightly more for boys than girls?

Leanne I don't know, except boys like mucking around with things and fixing things, and sort of because my brother's interested in computers, and science, and that.

Interviewer I see. Does that put you off an interest in science yourself, because you think it's a boy's thing?

Leanne No.

Interviewer No? You can still see that you could follow it through?

Leanne Yeah, if I wanted to.

Interviewer But you don't really want to?

Leanne No.

Interviewer Why not?

Leanne I don't think it would interest me.

Leanne's belief that she did not know much science must be viewed within the context of her school experience. Her Form 1 teacher had been an enthusiastic, over-confident, domineering male teacher responsible for all the Form 1 science in the intermediate school. He tended to 'brow-beat' his students by methods such as constantly firing a series of scientific 'facts' at them during any class period, irrespective of the particular lesson topic being presented. It is possible that even though Leanne may well have been exposed to more school 'science' than had many comparably aged students, she still felt her knowledge to be inadequate alongside that of her male peers and her previous male teacher, and that an intuitive male-science association developed at this time. This association would have been reinforced by her brother's expressed interest in science; her perception of her

father's interest, and her mother's lack of interest. It is also possible that a degree of antagonism had developed between Leanne and her Form 1 teacher and, in rejecting him, she tended to reject his values too, such as the rejection of his placing an obvious value on the importance of studying science. This rejection would not have been challenged by her current (Form 2) female science teacher who openly professed:

Teacher I know nothing about science and I'm too old to start learning about it now. The kids'll get all the science they'll need next year across at the high school.

A subsequent interview with her parents, conducted to explore the possible origin of some of Leanne's constructs, revealed them to be unable to give any guideline in science and not to consider science particularly important, for a girl [!]:

Father We really haven't got a terribly good idea on what, you know, what science really covers ... well, especially for a boy, I think possibly science will possibly come into, you know, into jobs ... I think it's possibly the - you know - you think of, you know, science is more - you think of as a boy being involved in more than a girl.

Leanne's father spoke candidly of the encouragement he had given to his son with scientific activities but support of a similar kind did not appear to have been offered to Leanne. It would not have been 'diplomatic' of the interviewer to suggest to the parents that perhaps they were not so concerned with providing Leanne with experiences which may challenge, develop, extend her skills of observation, exploration, problem solving, in 'things' scientific, as they appeared to be for their son. They appeared to accept Leanne's more passive behaviour in this field to an extent unlikely to have been accepted in Leanne's brother. The effects on the outlooks on science both their children would develop as a consequence of their parents' beliefs were not readily assessable but it is suggested they would be considerable.

Thus, to conclude this illustration, a summary of Leanne's outlook on science would include the following components:

- science is boring
- science is difficult and therefore studied only by 'brainy' people (and I am not brainy)
- science is unimportant in my life (my parents and my current teacher would agree with me)
- my parents, brother, teachers (last year's and this year's) and friends imply science is more for boys than for girls
- I don't know much about science, I don't want to know much about science, and to be a hairdresser I don't need to know much about science
- I don't know any scientists but I believe they are 'strange'

- . I have had only limited contact with science but I know I'm not good at it
- . my parents don't encourage me to work hard at science the way they encourage me with my maths and reading
- . I don't like doing science, I don't like reading science books and I don't like science programs on television
- . I will probably stop studying science as soon as I can.

It may be suggested that these components of Leanne's outlook on science developed in a particular social context which never, or rarely, identified the relevance of science for people in their everyday world but instead nurtured the belief that science is an esoteric discipline of value to only a small group of people (intelligent males?) in society.

Therefore, it was apparent to this investigator that, even before embarking on any secondary school level science studies, Leanne had developed a resistance to science which would very likely lead her to discontinue with a study of it beyond the school core requirements: that is, beyond the fourth form. It appeared that Leanne's outlook on science, even though it had developed in an apparent ad hoc fashion, if not challenged and transformed, was going to be very influential in determining her future subject choices, her possible vocational plans, and the nature of a wide set of subsequent beliefs and attitudes about science. Leanne appeared 'qualified', even as a Form I student, to contribute to the under-representation of girls in science.

Space limitations preclude the presentation here of a similar analysis to that above with respect to ethnic differences but this research revealed several. Polynesian students' personal construct systems contained proportionately more affective and value components than the non-Polynesian students, and fewer career components, and the influence of other people was noticeable. The Pacific Island students, within the Polynesian sample, appeared to be particularly influenced by their parents' beliefs and desires (in many cases, their reason for coming to New Zealand was to further their children's education), yet, perhaps because of limited contact with experience of an explicit scientific kind, the study of science was not perceived to be as important as the study of English and mathematics.

The parallel of sex-role stereotyping would be 'ethnic-role' stereotyping, and ethnic-role stereotyping was perceived by the Polynesian students to exist, and that while few students were able to articulate its presence, its influence was pervasive. Several points may be suggested which arise from this assertion:

- (a) As science was perceived by Polynesian and non-Polynesian students as being an academic subject, and many Polynesians (particularly the Maori students) did not have high academic esteem, as they rejected much of the school's curricula, they rejected science.

(b) As school was perceived primarily as preparation for work, and the stereotype of the scientist was the only model the majority of students held of vocational science - the 'model' inevitably being of a white-coated Caucasian male, working in apparent isolation from other people - the identification with the role of an individual applying aspects of science was not possible for the Polynesian students whose social affiliations were of a high priority in any work plans.

(c) Following from the preceding point, as the perceived nature of scientific enterprises was such that science was not apparently particularly concerned with people (but with formulae, abstract principles, and 'things'), it was not perceived as 'important'.

(d) Several students (including non-Polynesians) had expressed difficulty with understanding scientific vocabulary. As many of the Polynesian students (particularly the first and second generation Pacific Islanders) had impoverished English-speaking language backgrounds (many Pacific Island parents preferred to speak their mother tongue at home) they experienced greater problems of understanding the language of science than did their non-Polynesian peers.

WHY THE UNDER-REPRESENTATION?

It is suggested that socio-cultural factors operate differentially on girls and boys, and on different ethnic groups, to influence the development of different outlooks on science, and that these different outlooks are instrumental in determining the students' intentions to continue, or not to continue, with a study of science. Of these factors, stereotyping, both sex and ethnic, based on convenient, but often limiting and/or erroneous, beliefs, is the most identifiable. That is, girls and Polynesian students develop outlooks on science which differ from those held by boys and Europeans because society does not encourage, or expect, members of the former student groups to achieve as well as those of the latter groups:

You mainly see on science fiction movies, or dealing with science, you mainly see men and you hardly see any women scientists.
(Fourth Form girl)

I think that most Maoris think that the Maori's going to end up doing average jobs. (Maori student)

This lack of positive role models, in the school, the work-place, and the media, at a time when the students are becoming aware of their own identities and possible future plans, compound with early home experiential and socialisation patterns to result in outlooks on science which are rarely systematically examined or challenged.

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APPENDIX A

Mean percentages of girls and boys in the 5, 6, and 7 forms
who took science options for the five years 1976-1980 inclusively

	Fifth Form		Sixth Form		Seventh Form	
	Girls	Boys	Girls	Boys	Girls	Boys
Science	50.9	68.7	-	-	-	-
Biology	29.2	11.7	74.2	52.8	67.1	49.2
Chemistry	0.9	3.8	22.8	37.4	35.8	52.8
Physics	0.7	5.9	14.6	48.5	22.8	56.4

Source: Annual Education Statistics of New Zealand,
Dept. of Education.

Mean percentage of students classified as Maori and non-Maori
at the 5, 6, and 7 form levels who took science options
for the five years 1976-1980 inclusively

	Fifth Form		Sixth Form		Seventh Form	
	Non-Maori	Maori	Non-Maori	Maori	Non-Maori	Maori
Science	61.8	47.2	-	-	-	-
Biology	20.2	22.8	64.2	57.1	57.0	53.5
Chemistry	2.6	0.5	31.0	15.3	45.9	31.6
Physics	3.6	1.0	33.3	19.1	42.2	34.0

Source: Annual Education Statistics of New Zealand,
Dept. of Education.

STUDENT TEACHERS' UNDERSTANDING OF SCIENCE CONCEPTS

John Hope and Michael Townsend

During the 1970s science education in New Zealand followed overseas trends and moved from a knowledge or concept based approach to one based on skills and attitudes. The new syllabus for the first six years of schooling (Infants to Standard Four) was implemented in 1975. The trial syllabus for the next four years of schooling (Forms 1-4) has received much investigation through the Learning in Science Project (LISP) being conducted from the University of Waikato. The details of this research are reviewed elsewhere (Osborne, Freyberg, & Tasker, 1982; Osborne, Freyberg, Tasker, & Stead, 1982; Tasker, Freyberg, & Osborne, 1982), but a major finding has been that students often hold views about scientific concepts that are different from scientists' views. For example, Bell (1981a) found that less than 50 per cent of senior high school students normally classified worms and spiders as animals.

A number of misconceptions about basic concepts occur before the student enters high school, thus giving primary school teachers the responsibility for diagnosis and remediation. But Tasker *et al.* (1982) found evidence in an exploratory study that some trainee teachers hold naïve scientific concepts little different from those of primary school students. The current study was undertaken to examine the extent to which accurate scientific conceptions in certain physical and biological concepts are held by first year teacher trainees. Clearly, an assessment of the extent and nature of any scientific misconceptions would be important to the subsequent science training received by student teachers.

A second purpose of the investigation was to examine whether the understanding of physical and biological concepts is related to the sex of the student. Similar to the situation overseas (Kelly, 1978), more males than females in New Zealand study sciences at the senior high school level. Additionally, males and females focus on different areas of science. For example, figures taken from the Annual Educational Statistics of New Zealand for 1976-1980 reveal that for sixth form science students, proportionately more males (49%) than females (15%) studied physics, while proportionately more females (74%) than males (52%) studied biology. If these relative proportions are reflected among trainee teachers it may be that accurate scientific conceptions are proportionately greater among males in the physical science area and among females in the biological science area.

METHOD

Subjects

The subjects were the first year students training as primary school teachers at Auckland Teachers' College in 1982. There were 36 males and 146 females. Sixth form physics had been studied by 31 per cent of the males and 12 per cent of the females, while sixth form biology had been studied by 72 per cent of the females and 56 per cent of the males. Seventh form study of these sciences was low (less than 20% overall) and only two subjects held university degrees in science.

Instruments

Knowledge of science concepts was tested using the LISP surveys in physics (Osborne, Schollum, & Hill, 1981) and biology (Bell, 1981b) developed for this purpose. These are criterion based tests for which extensive data on high school student performance is available. The biology survey presents three sets of 10 diagrams of objects and requires the student to say whether each object is an example of a plant, an animal or something living, respectively. The physical science survey presents 17 questions in the form of diagrams representing the concepts of force, friction, and gravity and requires the student to select the correct interpretation of the concept from among several alternatives.

Procedure

Subjects were tested in groups of approximately 20 during normal lecture time in a subject other than science. The investigator (a science teacher at the college) handed out individual booklets containing the surveys and asked students to record their answers in the booklet. The survey was voluntary (no-one declined to participate) and untimed; most students completed in 20-30 minutes).

RESULTS AND DISCUSSION

Biological Science

The percentage of students correctly identifying each item as plant, animal or living was calculated for each sex. Mean performance across the 10 plant items was very high, being 95.6 per cent for males and 97.2 per cent for females. On only one item (seaweed) did the sex difference exceed 10 per cent, with fewer males (83%) being accurate than females (96%). These results are very similar to those obtained by Bell (1981a) with senior high school students. Pertinent to the second purpose of the study the proportion of female students exceeded that of male students on only three of the 10 items, although all differences were relatively small.

Correct identification of the animal concept was more variable. Although 'person', 'horse', 'pine tree', and 'fire' were classified with almost perfect accuracy, students had more difficulty with 'moth' (males 70% correct and females 62% correct), 'spider' (69% and 64%), 'fish' (75% and 73%), 'worm' (81% and 90%). Correct classification by the student teachers was generally higher than that reported by Bell (1981a) for sixth form high school students. For example, the proportion of the latter group correctly classifying the items spider, worm, dolphin, person, and horse was 48, 58, 76, 88, and 98 per cent respectively. Thus, the concept of animal appears to mature further beyond high school and significant numbers of student teachers may have difficulty in classifying some instances. Mean performance across the 10 items was 85.8 per cent for males and 83 per cent for females. Although the largest individual difference between the sexes on any item was only eight per cent, the proportion of correct females exceeded the proportion of correct males on only one of the 10 items.

Mean performance across the 10 living items was also high, with males (93.1%) and females (91.4%) having similar performance. Females exceeded males on only two of the items. 'River' was miscategorized as living by 24 per cent of the students and 'fire' by 15 per cent. Anecdotal comments suggested that some students in the latter instance may have been influenced by a television advertisement which refers to natural gas as a 'living flame'. The miscategorization of 'river' is also common in junior and senior high school students (Bell, 1981b). It may also occur in university students. Papalia-Finlay (1978) found that 67 per cent of female undergraduate students with an extensive science background assigned the concept 'living' to objects other than plants and animals. For example, 56 per cent designated the ocean as living. However, when the same students were asked to give a scientific or biological definition of 'living' they were able to do so. The author attributed the apparent inconsistency to the use of a broader sense of the word in the absence of being specifically asked to use the biological meaning, and states 'that young adults frequently do not choose to employ a biological definition of living does not necessarily imply that they are incapable of doing so' (p.138). This caveat is also applicable to the current results. It suggests that without a specific requirement to use the biological definition even an object like a stone may be seen as living (in the broad sense of being intermediate in the 'life' from mountain to grain of sand).

In summary, biological concepts were relatively well understood by student teachers although some scientific misconceptions still occurred, particularly for the animal and living categories. Overall performance was similar to or better than sixth form student performance. Sex differences were relatively small and there was no suggestion of higher female performance than male in biological science; performance

over all 30 items was 91.5 per cent for males and 90.5 for females. However, disregarding the size of the differences the proportion of accurate females exceeded the proportion of accurate males on only six of the 30 comparisons, a difference which was significant at the .01 level. Thus, the female proportions were consistently lower than the male proportions.

Physical Science

Three items involved the concept of force. The pattern of answers reflecting an incorrect Aristotelian view of motion, that force is in a moving body rather than acting upon it, was found in 49 per cent of the student teachers (54% of males and 48% of females). These results are similar to the Osborne *et al.* (1981) results for both fourth form (53%) and sixth form (53%) high school students. They also parallel the results of Watts and Zylbersztajn (1981) who found that 85 per cent of an English sample of 14 year olds associated force with motion. The correct pattern of results reflecting the physicists' Newtonian view was found in only 10 per cent of the students (males 11%, females 9%), which is again similar to Osborne *et al.*'s (1981) fourth form result (11%) though lower than the sixth form result (22%). Male and female proportions were similar on all items (an average difference of less than 5%), with the male proportion being higher for two of the items.

The concept of friction was tested using nine items. The first four items investigated friction and movement. As with force, a majority of students incorrectly associated friction with movement. Answers to one question revealed that 65 per cent of students believed that if there is no movement there is no friction; the proportions were the same for males and females. Answers to another question revealed that 53 per cent of students equated greater speed with greater friction; females (57%) were more likely than males (35%) to hold this view. Across the four items only 30 per cent of students held the scientifically correct view (40% males and 28% females). By comparison, Osborne *et al.* (1981) found the proportions to be 20 per cent at the fourth form level and 59 per cent at the sixth form level. The male proportion exceeded that of the female for two of the items, but apart from the speed/friction question (mentioned above) all differences were less than five per cent.

Two items investigated the relationships between friction and reaction forces and friction and heat. Accurate performance was relatively low on both items, being 15 per cent and 34 per cent respectively. Osborne *et al.*'s (1981) results for fourth and sixth form high school students were 12 and 20 per cent respectively for the friction/forces question and 38 and 77 per cent for the friction/heat question.

Thus, performance in this study was most similar to fourth form results. Some 45 per cent of males and 68 per cent of females incorrectly associated friction with heat energy. There were more accurate males than females for both of these items.

Three further items questioned whether friction occurs when a solid object moves over a solid and through a liquid or a gas. Across all three items correct interpretations were given by 58 per cent of the students (63% males, 56% females), indicating that they understood that friction occurred in all states of matter, but 11 per cent thought that all friction occurs in solids and liquids only. The overall proportion was similar to Osborne *et al.*'s (1981) fourth form proportion of 59 per cent, but below the sixth form proportion of 77 per cent. The proportion of males exceeded that of females for all three items, by an average of seven per cent.

The concept of gravity was addressed in five items. Almost all student teachers recognized that gravity is present at the earth's surface and a majority (54%) recognised that gravity is present on the moon (80% males, 48% females). It is of interest that 47 per cent of females answered that there is no gravity on the moon, compared with 24 per cent of fourth form students and four per cent of sixth form students (Osborne *et al.* 1981) and 80 per cent of English 14 year olds (Watts & Zylbersztajn, 1981). Only 37 per cent of students (46% males, 35% females) recognized the similarity of gravity in the lower atmosphere and at the earth's surface, and only 26 per cent (29% males, 25% females) recognized that gravity acts on satellites orbiting the earth. These two proportions are similar to the fourth form results (Osborne *et al.* (1981) of 35 per cent and 25 per cent respectively, but are lower than the sixth form proportions of 56 per cent and 57 per cent. A question concerning gravity under water revealed that 72 per cent of students (86% males, 68% females) held accurate views. Thus, students' conceptions about gravity are more inaccurate with increasing distance from the earth's surface. Male proportions exceeded female proportions for four of the five gravity items, with some large differences apparent.

In summary the student teachers held a number of inaccurate or false conceptions about physical science and their general level of performance was more similar to a fourth form level than a sixth form level. Sex differences varied across items with more males tending to be accurate than females; across the 17 items the mean accuracy performance was 65 per cent for males and 56 per cent for females. Chi square analyses revealed that there were significant sex differences on three items (two in friction and one in gravity). Disregarding the size of individual item differences the proportion of accurate males exceeded that of females on 13 of the comparisons, a difference which was significant at the .05 level.

Since the LISP surveys are not necessarily equivalent caution must be exercised in making direct comparisons between performance in biology and physics. However it is clear that student teachers do demonstrate basic scientific misconceptions about the world in curriculum material that is taught prior to the high school fifth form level where subject specialization by students normally occurs. The expectation of a disordinal interaction between sex and performance in biology and physics was not supported. But the expectation did receive some support in that student performance in biology was similar for males and females while the reduced performance in physical science was greater for females than for males.

Finally, it is clear that an extensive science learning component is essential for males and females at both school and teacher training institutions. However in circumstances where there are disproportionately fewer females than males studying science at advanced levels, and where there are disproportionately more females than males involved in primary teaching, special attention may need to be given to females in their physical science education courses during teacher training. But note that the results of this study suggest that although the proportion of males with accurate conceptions is consistently higher than that for females, the size of the differences is generally very small. Given that attitudes can account for at least 10 per cent of academic achievement (West & Foster, 1976) it is possible that an improvement in the less positive attitude of females toward science (Kelly, 1978) would eliminate any sex differences in performance.

Improvement in the teaching of science will depend on two factors. The first is an improvement in the teacher's personal concept knowledge, an improvement that may be assisted through a careful distinction between the denotative (definitional) and connotative (implicational) meanings of words (Sutton, 1980). The second is an improvement in the skills of detecting inaccurate conceptions in students, which does not necessarily follow from an improvement in knowledge. Watts and Zylberszajn (1981) found that some teachers with extensive science concept knowledge have difficulty in understanding why their students cannot assimilate concepts which to the teacher are logical and a matter of common sense. In a related study Nussbaum (1981) found that only half of his science graduates could detect examples of animism in pupils' work, and less than one third could detect other conceptual errors.

Science concepts consist of the sum of all connections to the other things the person knows. The problem for teachers is to learn the right connections themselves, and to learn to recognize the wrong connections in the students they teach.

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RESEARCH ON ALTERNATIVE FRAMEWORKS: IMPLICATIONS FOR SCIENCE TEACHER EDUCATION

Jeff Northfield and Richard Gunstone

INTRODUCTION

The term alternative frameworks is being used in this paper to identify the relatively recent wave of research which has explored student views of science phenomena. These student views have also been termed personal models of reality and student misconceptions but in all cases the approach is characterised by a desire to understand the views students acquire of natural phenomena and science concepts from their interactions with the world, and the specific origins of these views. The research efforts have identified the existence of alternative frameworks in areas of chemistry, biology and physics, with these student views frequently at odds with traditional views of science (e.g., Champagne, Klopfer & Anderson, 1980; Driver, 1983; Erickson, 1979; Gunstone & White, 1980; Nussbaum & Novak, 1976; Osborne, 1982; Schaefer, 1979). More important for this paper is the observation that these student views are very resistant to change and at this stage few guidelines exist to assist teachers.

The Learning in Science Project acknowledged the importance of communicating with and involving teachers in the research effort (Osborne, Freyberg and Tasker, 1979). Its action research approach can be endorsed from our experience with a small number of practising teachers investigating their pupils' explanations of scientific situations. At pre-service levels there are particular problems of introducing the ideas emerging from research on alternative frameworks. Yet this research thrust appears to have clear relevance for teacher education because of the implications for pupil learning and the proposed basis for new objectives of science teaching (Fensham, 1983).

The authors have been in a fortunate position of having a research interest in alternative frameworks of pupils and teaching responsibilities in the preservice education of science teachers. In reflecting on teaching practices over the past five years several responses to research outcomes can be identified. These can be placed in two categories.

1. Practices which have been carried out for many years but are now justified and modified to emphasize a deeper understanding of these new perspectives on pupils' thinking. Such reactions can be regarded as evolutionary and in some cases the shift in the way various activities have been explained to the intending teachers had not been noticed by those responsible for the course.

2. Activities introduced to address some aspect of the problem of understanding pupil learning.

The activities which are described below are taken from a one year end-on course leading to a qualification for secondary teaching. All intending teachers have graduated with science degrees.

REVIEWING SOME ACTIVITIES FROM ONE TEACHER EDUCATION PROGRAM

The activities can be seen as a response to the science background of the intending teachers or attempts to assist student teachers' understanding of their own learning or increase student teachers' understanding of children's learning. All three of these approaches are regarded as necessary in any program incorporating the outcomes of 'alternative frameworks' research.

The science background of intending teachers

All beginning science teachers will have to cope with a lack of knowledge, skills, and confidence with certain topics in school courses. The requirements of science in school years 7 to 10 can include astronomy, geology, and environmental science topics. Even school science topics related to the major and sub-major studies of teachers are often new challenges for the new teachers.

One approach to these background deficiencies is to provide a range of short courses extending from 1-8 hours in duration. Student teachers are required to undertake a minimum number of such courses, some of which are required depending on first degree background. Courses offered include Physics for Non-Physicists, Introduction to Microscopes, Microbiological techniques, Dissection techniques, Setting up Aquaria, Solar Energy.

In recent years we have gained a clearer understanding of some new dimensions of the science background of trainee teachers. The student teachers bring alternative frameworks to the pre-service program. (For example, we now know that there are college students in the U.S. who believe that one can use a cell to light a globe with just one wire; that there are Australian science graduates with chemistry majors who believe that the purpose of insulation around conducting wires is to keep the current in; that there are university Biology students in the U.K. who can give most elaborate and comprehensive Darwinian explanations to standard textbook problems while also believing that a Scandinavian family moving to the tropics should expect dark skinned progeny after two or three generations.)

It is clear that many successful (i.e., exam passing) students do not have their pre-instruction beliefs affected by teaching. It is also clear that the bulk of the teaching in university science departments does not come to grips with these fundamental conceptual issues.

It is obviously not possible to provide a one year pre-service course which includes formal courses needed to generate understanding in all relevant science areas. We are beginning to believe that a more useful approach is to aim to help student teachers come to understand their own learning. Understanding the origins of their own world views and the inconsistencies between these views and the accepted scientific views may be the most powerful approach for developing in teachers an ability to recognize and cope with the alternative frameworks held by children. Such an understanding of their own learning can also provide the trainees with an incentive to work independently on their own science knowledge. In the next section one attempt to address the trainee teachers' own learning processes is described.

Student teachers' understanding of their own learning

The approach to be briefly outlined was a five day course entitled 'Physics for Non-Physicists'. The participants were Biology method students who had selected this elective course from a list of 30 possible courses offered at this final stage of the pre-service year. It was made clear that the course was designed to examine the learning processes of the participants as certain concepts related to force and motion were explored. The course would begin with the students' existing concepts and assist understanding and development of these ideas. A more detailed description is available (Champagne, Gunstone and Klopfer, 1983). In this paper a brief outline of some important outcomes is set out.

The process of examining each concept was lengthy with considerable time devoted to discussion, observation, and argument about relationships between force and motion. Student reactions after one session dealing with prediction, observation, and discussion of falling bodies indicate the development of new insights into their own learning.

[The activity] enabled me to see how others see things and why they view them this way. Made one think hard to get a totally convincing argument for your side and any inability to do this gives you the suspicion that you are not in fact correct in your initial explanations ... helps in understanding our false misconceptions and being confident in our new ideas'.

'During group discussion I changed my mind about the forces operating on the falling bodies ... some people fight hard not to change preconceived ideas'.

'It feels strange to contradict oneself half an hour later. It's worth the lengthy time involved because I can have time to gradually understand the issue at point It's comforting to try to keep certain ideas forever even if there's a chance that they may be wrong'.

'I'm shattered! Didn't realize how devastating it could be to have a deep-rooted belief proved wrong. Can I blame my physics teacher? ... I'm mentally exhausted after each session and the effort to hold out when I'm wrong is very draining'.

Student reactions during subsequent sessions, as shown by transcripts of discussions, suggest that they developed a learning process from the falling bodies experience. When conflicts arose between world views and observations for other phenomena it was common for students to use the falling bodies experience to argue with each other or even themselves about the nature and origins of the conflicts.

Whether the impact on participants is transferred to later teaching of pupils is problematic. The experience with this course has encouraged the authors to look for opportunities to modify the approach taken in other short courses. If 'teachers teach the way they were taught' the experience provides a different model for the trainee teachers to consider. The course should also provide a valid model of the learning problems experienced by school science students with the teacher able to identify in a very personal way with pupil concerns.

Student teachers' understanding of children's learning

The preservice course commences with a period of seven weeks before student teachers undertake their first teaching practice. This first seven weeks has always been seen as an opportunity to prepare the trainee teachers for the teaching experience. Activities such as microteaching, teaching individual pupils, and observation visits to schools have been seen as gradual increases in student responsibilities for planning and teaching prior to full responsibility in the classroom. In recent years the rationale for these activities has been modified. The tasks set for the student teachers have been designed to emphasize the understanding of individual pupils. The authors would now argue that it is necessary to appreciate the value of understanding the individual pupil before the demands of group management take over with class responsibilities in teaching practice.

One of the preliminary activities requires student teachers to teach one year 7 pupil for one 50 minute session. It is suggested that teachers choose a topic where they have some confidence and the assignment task is to reflect on the pupil's initial concepts, language, and learning processes. The trainee teachers' reactions to this activity indicate that some insights about individual pupils and learning are obtained.

'It was answers such as this which made me realize that I had underestimated Lesley's ability for logic ... I noticed that Lesley required a long time for thought before she answered'.

'... Year 7 students need to learn about things that they can see'.

'It then struck me that these kids may have had a language all of their own. It seemed that before I could teach them, they would have to teach me'.

'I don't think there is anything wrong with expecting a lot from students but where I made the mistake was in being disappointed that [he] did not understand early in the session, instead of just realizing that there was further to go to reach expectations'.

A visit to a primary school is also undertaken. This is an opportunity to interact with pupils who are often more willing to discuss their school and learning than their secondary counterparts. Like the one-to-one teaching activity the day with primary pupils is organized to make student teachers aware of the existence and possible origins of alternative views of science concepts. There is therefore an attempt to encourage a diagnostic attitude as part of teaching. Perhaps student teachers begin to appreciate how little is understood about student learning in science classrooms.

PUTTING IDEAS INTO PRACTICE

In some ways making student teachers aware of the existence of alternative frameworks in their own and their pupils' thinking is not a difficult task. Dealing with the implications for their later teaching roles provides a further (and perhaps greater) challenge. The identification of alternative frameworks in the thinking of the trainee teachers can prove very disturbing for individuals. The student teachers constitute a successful group after a minimum of 15 years of education with a specialization in one or more areas of science. Implicitly, the new teachers are being asked to question the teaching, learning, and outcomes of science education.

All that has been discussed above has implications for the nature of the science to be taught at the secondary level. Student teachers should understand that, for example, a curriculum structure which begins with a definition and then moves to the application of a formula to a number of numerical problems will result in very little learning. If there is concern with children understanding science concepts, both the content to be taught and the time allocated to teaching the content need to be rethought. Crowded curricula do not allow for the diagnosis, observation, and discussion associated with teaching and learning based on the existing frameworks of pupils. Modes of examination too often test the extent to which knowledge has been acquired but ignore the conceptual basis of this knowledge.

It is important that student teachers do not underestimate the problems of bringing up even incremental change in existing curricula and teaching methods. The student teachers who experienced the five day course in 'basic physics concepts' will understand the tendency for individuals to cling to concepts developed from their real world experience. It will take a great deal of time, patience, and experience for teachers to subject such personal views to examination and possible revision in the thinking of their pupils. At another level curriculum change will also be difficult. Time will have to be found in existing science programs and testing procedures will need to reflect a greater concern for understanding basic concepts.

Two factors are operating which may reduce the difficulty of change at the school level. Firstly schools in Victoria have curriculum autonomy for years 7 to 11. In the process of curriculum decision-making there is an opportunity for well justified curriculum changes to be implemented in science programs. In the latter part of their preservice year student teachers are placed into groups to develop a curriculum program given a particular topic or theme for a school term (12 weeks). They are therefore required to argue an approach as an individual within a group of three or four and finally as a group in a larger seminar comprising staff and other students. Such a simulated activity can therefore give some practice in the problems of implementing ideas.

A second factor which may provide some support for teachers wishing to begin with children's alternative views is the small but increasing number of teachers valuing the approach in their classrooms. Continued research and support is required for teachers attempting to start with a learner's ideas and allow the learner to consider other explanations in an independent way. Encouraging developments continue to emerge from the Learning in Science Project which has reached a stage where teachers have become involved in the research and have provided ideas for other teachers (Osborne, Freyberg, and Tasker, 1982). Baird and White (1982) and Gibbs (1981) are also adding to a growing literature which directly supports teachers encouraging independent learning in their pupils.

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HANDS ON HEADS: SCIENCE AND THE INTELLECTUALLY IMMATURE HIGH SCHOOL STUDENT

Anthony Blake

INTRODUCTION

Of the many social problems currently facing Australia and other western nations, the phenomenon of youth unemployment has been receiving special consideration. The recent national report, Learning and Earning (Commonwealth Tertiary Education Commission, 1982), drew attention to a falling participation rate in senior secondary and tertiary education. The new Australian federal government has incorporated education and youth affairs into one portfolio; a clear indication of the relationship identified between schools and the difficulties facing the country's youth.

What sort of preparation should our secondary schools be providing for their students? In Australia the general tendency has been to provide a conventional, academically-oriented curriculum designed principally for students destined to complete the six years of schooling. For those students who appear destined for early school leaving, we have crafted a range of programs involving work experience and 'preparation for life' experiences, often under the rubric of 'transition education'. Often science has no obvious place within such programs as it is seen as intrinsically uninteresting and intellectually too demanding. Even within the conventional academic program, the amount and nature of science are variable. Yet, during the 1960s and 1970s, science was hailed as an essential component of the curriculum and a number of writers argued that science, taught by a process of enquiry, could facilitate the intellectual development of learners (e.g., Blake, 1973; Karplus & Thier, 1967; Lawson & Renner, 1975; Renner & Lawson, 1973).

Unfortunately these fondly-held hopes for science have not been realised in general and Fensham (1981) criticised the assumptions, even arrogance, underlying what he termed 'heads' science; that is, science education which emphasised the development of broad, abstract, conceptual schemes using an enquiry approach to learning. He advocated as an alternative a science curriculum which emphasised the systematic development and mastery of practical skills based on scientific knowledge, calling this approach 'hands' science.

This paper presents some research findings which identify a proportion of the secondary school population that is receiving little obvious benefit from secondary education. It raises the possibility of merging the benefits of 'heads' science and 'hands' science as a model for a compensatory education program for this group of students.

A LONGITUDINAL STUDY OF INTELLECTUAL DEVELOPMENT

A seven-year longitudinal study of intellectual development was undertaken using the Piagetian conception of intellectual development. Full details of the study are presented elsewhere (Blake, 1983); this paper focusses on one facet of the result of the study.

Procedures

Students from metropolitan Melbourne and the Riverina region of New South Wales were employed in the study. A random sample of 164 students in Years 7 and 8 was drawn in 1976 (53 Year 7 students from Riverina schools, 51 Year 7 students from Melbourne and 60 Year 8 students from Melbourne). These students were regularly examined using a battery of Piagetian tasks to determine levels of intellectual development. A complete description of the testing schedule and procedures is given in the full report of the study (Blake, 1983). It is sufficient to note here that students were tested several times during their stay at school with a battery composed of the following tasks administered in clinical interviews:

- Conservation of weight
- Conservation of displacement volume
- Separation of variables —
- Equilibrium in the balance

Results

The initial testing of the sample in 1976 revealed a cohort of students in Years 7 and 8 who were categorised at the Piagetian stage of early concrete operations. This paper is concerned with a closer examination of this group.

Of the total sample of 164, 33 were initially classified as early concrete-operational, 23 of whom were female. This represented about 20 per cent of the sample. To the extent that the random sample epitomised the total school population, this must be regarded as a sizeable group of students in the first two years of secondary school showing pronounced intellectual immaturity.

From the initial clinical interviews, it was clear that each of the 33 students was unable to

- (i) conserve weight;
- (ii) conserve displacement volume;
- (iii) use logical multiplication in compensating for different lengths and different thicknesses in bending rods (i.e., to comprehend that 'thinner x shorter = thicker x longer');
- (iv) isolate and control variables in order to test hypotheses;
- (v) use ratios and proportions in solving problems with a balance beam.

The general ability to conserve weight was instrumental in categorising these students as early concrete-operational. The longitudinal study traced their progress through school, and Table 1 shows the pattern of school retention shown by this group, initially classified as early concrete-operational, in comparison with other cohorts initially classified at the higher Piagetian levels of intellectual development.

TABLE 1.

A Comparison of School Retention in Four Cohorts
Based on Initial Categorisation into Levels of
Intellectual Development.

Level of Intellectual Development at Initial Testing	Year of Leaving School			
	Before Year 10	Year 10	Year 11	Year 12
Level IIA- early concrete operations	14 (42.4%) (M=4, F=10)	12 (36.4%) (M=4, F=8)	2 (6.1%) (M=1, F=1)	5 (15.1%) (M=1, F=4)
Level IIB- complete concrete operations	26 (31.3%) (M=13, F=13)	30 (36.1%) (M=19, F=11)	11 (13.2%) (M=8, F=3)	16 (19.5%) (M=5, F=11)
Level IIIA- Early formal operations	7 (16.3%) (M=4, F=3)	14 (32.6%) (M=8, F=6)	0	22 (51.1%) (M=16, F=6)
Level IIIB- complete formal operations	0	2 (40%) (M=2, F=0)	1 (20%) (M=1, F=0)	2 (40%) (M=1, F=1)

M = no. of males; F = no. of females

Approximately 42 per cent of this most intellectually immature group left school before Year 10 and a further 36 per cent left at the end of Year 10. Hence, only about 21 per cent proceeded to the senior years of secondary school.

Table 2 presents the results obtained at the final testing of each of the 33 students initially categorised as early concrete-operational prior to their departure from school. They are shown according to sex and the results are aggregated into three cohorts:

- (a) students who left school prior to Year 10;
- (b) students who left school during or upon completion of Year 10;
- (c) students who proceeded beyond Year 10.

The following features emerge from the results:

- 1 About 20 per cent of students in the first two years of secondary school are at the stage of early concrete operations (at least in Melbourne and the Riverina), and approximately 70 per cent of such students are female.
- 2 Approximately 42 per cent of this group of students leaves school prior to Year 10, 72 per cent of whom are female.
- 3 From Table 2 it is evident that students leaving school prior to Year 10 and, to a lesser extent, after completing Year 10 continue to exhibit marked intellectual immaturity.
- 4 Table 1 shows that some students, albeit a small minority, initially categorised as early concrete-operational, complete secondary school. Table 2 indicates that those students proceeding beyond Year 10 show evidence of intellectual maturation.

DISCUSSION AND IMPLICATIONS

The reason for extracting these results from the longitudinal study is to emphasise that this group of intellectually immature students exists and apparently is not being well-served by the school system, since its constituents by and large do not stay at school, but leave still displaying a pronounced degree of intellectual immaturity. Although it is conceivable that such students exhibit a rapid intellectual maturation upon leaving school, there is no evidence in support of the possibility. On the contrary, the little evidence collected suggests that intellectual growth continued more rapidly in adolescents who remained at school than in those who left school early (Blake, 1983).

TABLE 2: Results of Performance on Piagetian Tasks at the Final Testings in School for the Cohort of Students Initially Categorised at the Level of Early Concrete Operations.

		Number (%) Within Cohort Able to Demonstrate Each Intellectual Skill at the Final Testing Before Leaving School.					
Piagetian Task	Intellectual Skill	Students that Left Prior to Year 10		Students that Left During/End Year 10		Students that Proceeded Beyond Year 10	
		Female	Male	Female	Male	Female	Male
Conservation of Weight	Able to conserve weight	2(20%)	2(50%)	7(62%)	4(100%)	5(100%)	2(100%)
Conservation of Displacement Volume	Able to conserve displacement volume	2(20%)	2(50%)	3(37%)	2(50%)	4(80%)	2(100%)
Separation of Variables ("bending rods")	Able to use logical multiplication in compensation for differences in length and thickness	3(30%)	4(100%)	8(100%)	4(100%)	5(100%)	2(100%)
	Some evidence of being able to isolate and control variables in order to test hypotheses	0	0	4(50%)	0	3(60%)	1(100%)
Equilibrium in	Some evidence of being able to solve problems using proportions	1(10%)	0	4(50%)	1(25%)	2(40%)	2(100%)

Unfortunately there is no information about the reasons which caused some of this cohort of students to remain at school and complete secondary education whilst the majority left. Clearly, level of intellectual development alone is not the determiner of success at school, or of desire to remain at school. It is likely, however, that improving the intellectual capacity of this group of students would improve their school performance and possibly their retention rate. The question, therefore, arises as to whether a program of compensatory education could be devised for this purpose.

Compensatory Education for Intellectual Immaturity

Hobbs and Robinson (1982) have noted that, over the past two decades or more, educators have been led to believe that, by adolescence, it is too late to reverse any cognitive deficits. Hobbs and Robinson (1982) attacked this view as a myth which has distorted the making of educational policy in the United States and probably elsewhere. In support of the proposition that cognitive deficits in adolescence can be remedied, they cited, in particular, the work of Feuerstein *et al.* (1981). Studies by Feuerstein and his colleagues (Feuerstein *et al.*, 1979, 1980) indicate some success in improving intellectual performance in learning-disabled, culturally deprived adolescents.

The procedures used by Feuerstein and his colleagues involve the application of a specific intervention technique called instrumental enrichment. The technique involves use of pencil-and-paper exercises incorporating perceptual and logical tasks. These exercises are intended to be 'content-free'. Whilst the technique may produce desirable results, it is quite clinical and unrelated to the general school curriculum.

In contrast to the Feuerstein approach to cognitive modifiability, I wish to propose for these immature adolescents an alternative form of compensatory education program which would be overtly embedded in the school curriculum. It is possible to confront students with intrinsically interesting, real situations which involve the same forms of perceptual challenges and logical reasoning as found in Feuerstein's pencil-and-paper exercises. The medium proposed is the science curriculum and here we must return to Fensham's 'heads' and 'hands' science.

Fensham's 'hands' science, or 'Tom Sawyer' science (Fensham, 1981), has a strongly utilitarian flavour. Scientific knowledge is acquired for specific purposes - to 'get jobs done'. In the throes of 'getting the jobs done', Fensham sees occurring the development and mastery of useful practical skills. This description is reminiscent of the purposeful play of children and adolescents which is geared to 'getting a job done'. The building of models, billy carts, kites, underground hideaways, tree houses and so on all involve the application and refinement of knowledge and practical skills.

This list of activities may read like a catalogue of the play activities of a generation past; before television, video recorders, computer games, prefabricated kites and so forth. Perhaps it is, but it is interesting to speculate to what extent the phenomenon identified in this paper is related to a deficiency of this form of play. That is, to what extent may prolonged inability to conserve physical quantities, to compensate for variables and to be able to systematically control variables, be due to lack of encouragement and/or opportunity to use hands and heads together during play? For that matter, how much opportunity has been lost with the declining need for children to engage in regular household chores? There are elementary experiences in conservation of weight, control of variables, even proportionality, in using an axe to chop wood.

This leads to the proposal for a science-based compensatory education program. The basis for such a program would be Fensham's 'hands' science. That is, a structured curriculum in which science knowledge grows from the application of practical skills, but in highly utilitarian situations. However, incorporated into this basis would be the fundamental characteristics of 'heads' science; development of situations which encourage perplexity, cognitive dissonance, or what Piaget termed disequilibrium. In a sense, 'hands' science provides the framework and emphasis for the program and 'heads' science defines the instructional process.

The basic inadequacy of the 'heads' science of the 1960s and 1970s was twofold. Firstly, it was overly pre-occupied with developing a curriculum sequence which reflected the development and consolidation of major conceptions in science. Such a curriculum model may be regarded as elegant by scientists and philosophers of science. It is difficult to justify, however, from a psychological perspective or from a needs-based perspective. Secondly, it attempted to engage students in intellectual enquiry at levels of abstraction which were beyond many. Again, this is difficult to justify from a psychological perspective.

The proposed approach is an attempt to rescue the baby whilst throwing out the bath-water, by incorporating an enquiry approach in a curriculum firmly rooted in real, practical situations. Such curriculum materials are not unique. Much of the ESS materials confront students with everyday situations (e.g. 'Kitchen Physics'). Similarly, Science 5/13 materials concentrate upon commonplace, interesting phenomena. It is also possible to envisage the incorporation of materials developed more from a 'heads' science perspective into a 'hands' science context. For example, the SCIS materials on Relative Position and Motion could be developed in the context of orienteering and exploration activities.

These examples are inadequate, however, for they are merely tinkering with the existing situation. The appropriate moulding of 'hands' science and 'heads' science requires a new curriculum model. In my view, this model should, like SCIS, attempt to foster intellectual maturation by developing a carefully-structured sequence of enquiry. But the sequence of enquiry should be based upon development of useful practical skills and associated scientific knowledge. This sequence would have to be determined, not by an analysis of the conceptual structure of science, but by an analysis of the needs confronting students in their everyday world.

A science program of this nature is being proposed as compensatory education for intellectually immature adolescents. Implicit in this proposal is the contention that adolescents who are unable to conserve weight or volume and who cannot isolate and control variables by Year 9 or 10 are, in general, victims of lack of experience: physical and intellectual. However, it is worth considering this form of junior science education for all adolescents. After a course of this nature, those interested in pursuing science further may be better prepared for more 'heads'-orientated senior science than is presently the case.

CONCLUSION

The intellectually immature students described in this paper leave school early and form a component of the unemployed youth seeking jobs. In this regard, Stipek (1981) has commented:

Early school leaving may not be advisable for low-achieving students. Until adolescents have mastered basic skills and achieved a level of cognitive development that will allow them to function as responsible adults, they should not be employed in jobs which are unlikely to contribute to these skills. Such a policy does not solve the problem of the school's poor record in assisting these educationally-handicapped adolescents (p.135).

At present, while such students remain at school, they are encouraged into transition education programs. Yet, according to Hobbs and Robinson (1982) and Stipek (1981), there is little evidence of such programs assisting with youth unemployment. Nor is there any evidence indicating that such programs improve basic educational skills and level of intellectual development.

However, after reviewing Youth Employment and Training programs, Mangum and Walsh (1978) wrote, 'It is the conclusion of most literature in the field that success in the work place is directly and inseparably related to the level of basic educational skills attained' (p.104).

Hence, programs of compensatory education for adolescents may be a better national investment than concentration on specific employment-orientated skills. Programs which encourage adolescents to remain at school, provide them with practical skills, and facilitate intellectual maturity, are likely to be a better long-term solution to youth unemployment. It is in this context that the proposal for a science-based compensatory program is suggested.

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BACKGROUND MAPPING OF TEACHERS' COGNATE PERCEPTIONS OF ASEP UNITS

Rod Fawns

This project 'Background Mapping of Key units in the Development of ASEP' (Fawns *et al.*, 1982) was funded by the Curriculum Development Centre (CDC) in support of proposals to rewrite certain ASEP units and develop several new units.

RESEARCH PURPOSES AND PROCEDURES

The prime purposes of the CDC Project were to

- 1 provide those responsible for writing the next generation of ASEP units information about the original units. The information provided in 21 case studies reviews included a concept map drawn by an experienced teacher and a student teacher who had never used the unit, together with evaluative comments on the preferred teaching sequence and concept difficulty. The implications of the findings were described by the author in the summary report entitled 'The Place of ASEP in Australian Science Education';
- 2 assess the impact of curriculum ideas implicit in the ASEP units on teachers' understanding and organization of science teaching. By engaging the teachers in the task of representing the conceptual relations in the unit it was hoped to gain some insight into the way the teachers perceived scientific knowledge in their teaching.

This paper is an assessment of the value of using a mapping and interview strategy to investigate teacher perception and the deployment of science materials.

The Sample of Teachers

The teachers were all volunteers drawn from Melbourne high schools, mainly in the poorer Western suburbs. Student teachers were volunteers drawn from the Diploma in Education Program at Melbourne University.

Unit Mapping Procedures

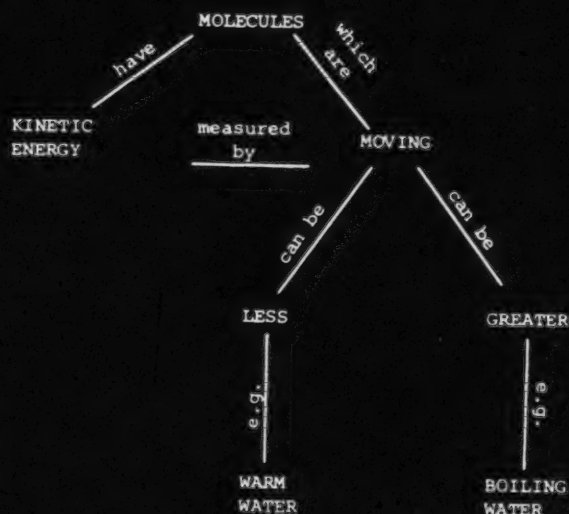
Each teacher was asked to complete a concept map before answering the questions which followed about pupil understanding, organizing ideas, teaching sequence, and boundaries of concern. The general procedure comprising mapping activity and interview was similar to that of other studies analysed by Fensham, Garrard, and West (1982).

The main distinguishing features were that (1) an 'ASEP unit' as a whole rather than a 'scientific concept' was the entity to be described in the map; (2) each map was drawn by a teacher; (3) informal comparisons between maps were attempted.

Directions for the construction of a map for each Unit were adapted from Novak (1980).

- 1 Teachers were presented with an envelope which contained a number of slips of paper on which were written some of the concepts contained in the ASEP unit. Blank slips were included for the teacher's own additions.
- 2 Teachers were asked to arrange the 'concepts' on a sheet of A4 paper, starting with the most inclusive at the top, followed by the next most inclusive, etc.
- 3 This procedure continued until all the concepts had been laid out. The teachers were then asked to establish relationships by drawing lines to connect the concepts, and to write a statement on the lines.

e.g.,



- 4 Teachers were asked to attach the map to a sheet of A4 paper when completed.
- 5 They were asked to show where linkages were weak (by marking the map with a W), and where linkages were strong (by marking the map with an S).
- 6 They were asked to draw a circle around any concepts which they had added to those provided.

FINDINGS AND COMMENTS ON METHOD

One student teacher and one teacher were asked which concepts they considered in each unit to be most important and unifying, and to illustrate interrelationships amongst these concepts. They were asked to show this in a concept map developed in a procedure described above. An example of the maps drawn for one ASEP unit 'Electric Circuits' are shown in Figures 1 and 2.

The teachers reported that they found the task difficult and often constructed several revisions of a map before arriving at the one which they felt represented their views of the relationships between the concepts they taught in the unit. Many felt that some variation was to be expected amongst maps drawn by different teachers for the same unit.

Generally, the student teacher map and the teacher map for each unit were quite similar. The same words generally appeared at about the same level in each hierarchy. Most variations occurred at the lower levels of the hierarchy and probably reflects more the degree of attention to detail rather than disagreement about higher level relations.

All student teachers and experienced teachers shared the view that the word at the top should represent a formal theoretical principle. It would seem, however, on logical grounds just as appropriate to draw a map which placed a word, such as 'radio' on the top of the hierarchy rather than on the bottom line as in the student's map Figure 1. There is implicit in the hierarchies an apparent consensus about the purpose of science teaching towards systematic theory as the pinnacle of learning and direction of science teaching. Certainly almost all the experienced teachers reported that they needed to step in to underline high level relationships in the concept map in the activities, particularly in the options. Interestingly, while the experienced teachers generally stuck to the published sequence, the student teachers 'possible teaching sequence' (flow chart for each unit) usually integrated the option activities in the core. They felt the choice about what was 'core' and what was 'option' was arbitrary in many units. In general, the concept words that experienced teachers added to the students' maps appear as additional theoretical points that can be illustrated by the unit. Often they were ideas that would be found in traditional science texts on the topic and which refer directly to higher level studies in one science. However, in 10 out of 21 reviews, teachers said they updated or broadened environmental dimensions of a unit. The teachers' view of the map is summarized in the following statement by one teacher: 'The concept map was what I considered to be most important from my experience'. That experience would appear on the evidence of the maps not to be significantly different from that of student teachers.

STUDENT TEACHER'S UNIT MAP
ELECTRIC CIRCUITS



FIGURE 1

ELECTRICITY



It would seem that teacher epistemologies are not drawn from close observation of pupil understanding, but rather reflect familiar disciplinary ideas. The author found however, that this impression is exaggerated by the formal logic of the concept mapping task. Most of the teachers would have agreed with the remark made by one, 'I am not sure that it really reflects the way I teach the unit'. The unit the teacher sees in the 'electric circuit' unit may not lie in the familiar logical relations of the language. This point is taken up later. The teachers' purposes should be gauged also by reference to responses to the questions they were asked about student learning. Nevertheless, student teachers and teachers generally identified the words in each unit as parts of a natural hierarchy. They also felt this hierarchy was shared with the authors of the unit. As one teacher explained, 'In the construction of my map, I was guided by what the authors obviously had in mind by the key words we were given'. This confidence in the objectivity of their epistemologies is important. Fawns (1982) argues that this confidence is based on the permanence of certain privileged paradigms of science in science teaching and the appeal of visual imagery of learning science. Conceptions such as 'seeing is believing', 'careful observation', 'nature study', the 'structure of disciplines', the 'demonstration' tend to fuse perception and knowledge denying the intellectual leaps required by the learner to construct the teacher's meaning when he points at something.

Mapping and Charting Techniques in Curriculum Organization

A Task Facilitation

Students and teachers interviewed felt that the concept mapping was a personally rewarding procedure. One teacher volunteered 'I find that my understanding of the area is facilitated by this type of structure'. It is interesting that many felt the form of the map was most significant, that the relationship between ideas in the unit was something worth further analysis. They also felt that, whilst the maps were to some extent idiosyncratic, there would be meaning, indeed considerable value, in offering one or more concept maps and flow charts to future teachers of each unit as a way of representing its 'structure'. By this use of the word 'structure' they meant purpose.

It appears that to reduce the problems of curriculum development to those of charting and mapping is a practical and useful way of constructing and delineating the contexts of a curriculum in the image of the discipline. Most teachers see this as a significant virtue. As one teacher remarked, 'My map of Solar Energy indicates a rather traditional analysis of concepts - a physicist could possibly have a more cogent way of looking at the area'. There is value in research investigations of teacher epistemologies to employ such techniques and probably to encourage their use in self-analysis by teachers in a variety of curriculum development tasks, including syllabus flow charting (Fawns, 1979).

The vast majority of science syllabi in Victorian secondary schools give, as these syllabus charts show, formal attention to balancing the time allocated to physics, chemistry, and biology in each year. It is possible, of course, that this diplomatic rule of thumb for a 'sound' science course has inhibited the appreciation of a realistic view of science and science teaching, and inhibited discussion about alternative organizations of understanding.

B The Ideology of the Map in Curriculum Organization

The application of a research technique to the problems of curriculum organization can of course transform the technique. Inglis (1975) in Ideology and the Imagination points to the danger in the over emphasis on rational flow chart planning as the only end of all means in curriculum development. The point of the mapping techniques may be taken to be the identification of purposeful action directed to an end, moving in the direction of the arrows, or as in its arrangement of hierarchy. Adhering too strictly to such an approach, he argues, one is likely to forget that individual action, idiosyncratic learning, or the science not found in standard texts, may bear no relationship to flow chart rationality or orientation. In other words, the flow chart has a tendency to predicate all human actions and learning within its systems approach which defines efficiency in its hierarchical taxonomy. We become aware that, narrowly perceived, the teacher's map is transformed into a narrow precinct, defined and delineated by an autonomous body of knowledge with its peculiar syntax and conceptual structures. The teacher often meant something more. We found in discussions with teachers that the words in their semantic maps have a meaning a teacher has given them. For example, to the teacher who drew the concept map Figure 2 the words 'electric circuits' had a more complex cultural meaning than could be sensed in his uninterpreted map. To him the central organizing feature of the unit and the map is the idea of the image of the electric circuit, that is the circuit diagram. It is in the middle range of the hierarchy that he operates as a junior science teacher. It is in his enthusiasm for the way he can organize the other ideas in the unit around the central idea of these dynamic diagrams that he described his purpose as well as his perception of the unit. The beauty of the concept of the pictorial 'electric circuit' lay for him in its economy and power. He saw the electric circuit as a representative of physical systems in general - infinitely variable, with interchangeable and integrated components and functions. There was great economy in the circuit's predictable obedience to a few simple laws. The pedagogical power in the diagram appealed to him. The amenability of electric circuits to this sort of portrayal is highly significant. The circuit diagram is useful as a vehicle for organizing and surveying information and later as the basis of some speculative gaming and assessment by student and teacher. This image of the electric

circuit he saw as the epitome of economy and power as a paradigm of science and science teaching. That is why he continues to use the unit. For the student, who drew Figure 1, 'circuit diagram' refers to a few pages in the ASEP text.

CONCLUDING REMARKS

In this research project teachers were asked to describe a number of ASEP units. The teachers' description of each unit was assumed to point to the teachers' instructional aims. This description was attempted by embedding a mapping exercise in a questionnaire interview with a small number of hard-pressed teachers of science.

Informal comparisons between the maps drawn by experienced teachers and inexperienced teachers were made. The strong impression gained from inspection of the maps is that what counts as justification for science teaching is its theoretical location in the disciplinary matrices of 'physics', 'chemistry', and 'biology'. Interpreted in this framework it would appear that ten years after the introduction of ASEP the key words the teachers used in justifying or describing their units tend to take them significantly from their privileged place in structure of university disciplines, rather than from common language context of that knowledge. This however appears to be too simplistic a judgement on the learning of these teachers. Unities were found which can be attributed to the use of ASEP.

For example, 'maleness and femaleness' has become a generative theme for the teacher who struggled against the anatomical definitions proposed in the ASEP unit.

Humanizing reflections on the roots of human behaviour, instinct and learning are on the agenda of the teacher who reviewed 'mice and men'. For one teacher at least the circuit diagram is a symbol of the economy and power in science. None of these attributes can be said to be self-evident in the formal language of the unit maps. The teachers sought public justification in this formal language of convention.

It appears that the unit maps drawn by teachers may be taken as a projection of a stable 'cognitive structure' in the sense that it reflects relations the teachers feel will not change. However each word used in the maps can be seen as connected to many other social images, some more important than others in the teachers' perception of the usefulness of the unit. As Bruner (1958) observed the imagery of a scientific theory has an immediate resonance with the dialectic of experience. It may not be the stuff of superficial conscious experience, but the interest engendered in the teachers by the abstract imagery of the concept mapping exercise and the conversations which followed suggest that it may be valuable in researching the teachers' experience of the seventies with ASEP.

For this purpose a theoretical stance which attributes primary significance to the relationship of the ideas and beliefs of science teachers and the imagery of scientific theory (Green, 1968; Inglis, 1975; and Kilbourn, 1980) can be contrasted with that of Kallos and Lundgren (1976), Young (1979), and Smith (1983) who see science teaching to be determined by certain social framing factors. Perhaps one of the beliefs that many teachers hold about the ASEP materials fits the commonsense physics of the age - closed and mechanical systems are being superseded.

There seemed to be a gnostic or therapeutic value in the mapping activity as in networking ideas. The teachers seemed to see it as an invitation to play around with and talk about unities of thought and action. Formal connections seemed to be important as did informal connections. This research in attempting to examine or detect the crystallization of new unities in science teaching through the use of ASEP seemed to serve a useful professional function for teachers.

Claims about teacher constructs demand attention indeed as much as those of children. One of the most important contributions that curriculum in science can make is to assess the impact that curriculum ideas, such as those implicit and explicit in ASEP, have on teachers' understanding and organization of science teaching. Cognitive mapping seems to offer hope of unlocking the gate to this secret garden. However, there is a need to be aware of the limits implicit in the use of the technique which may be seen to endorse the view, that Fensham (1980) rejects, that all that counts as justification, is that knowledge within the various disciplinary matrices constituting the culture of the day.

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DIMENSIONS OF COGNITIVE DEMAND

Gloria Dall'Alba and John Edwards *

INTRODUCTION

Most learning theories encourage the educator to present material at a level appropriate to the learners. However they do not speak with one voice when it comes to ways of deciding on that level. Many educators, finding that "the experts" disagree or that their alchemical language is too remote from classrooms, settle back to the reassurance of established methods.

In developing an instrument to reveal the cognitive demands of secondary science (Edwards and Dall'Alba, 1981) a possible theoretical framework emerged. Four dimensions were found to be sufficient to allow a clear and justifiable discrimination, in cognitive terms, between the demands commonly made on secondary science students.

This paper identifies the features of a cognitive task which determine how demanding it is and outlines an underlying theoretical framework. It also describes the way in which such features interact and hence determine the demand of the task.

The concept of cognitive demand as described in this paper has direct application to secondary science lessons, materials, and programs. It may be used for review purposes, in lesson planning, program evaluation, school-based materials development, and in formulation of clear objectives.

THE SEARCH FOR A FRAMEWORK

Learning theories and hierarchies suggest several means of differentiating between types of cognitive science tasks (Bloom, 1956; Taba, 1962, 1967; Bruner *et al.*, 1966; Gagné, 1970; de Bono, 1976; and the interpretation of Piaget in Novak, 1977; in ASEP, 1974; in Karplus, 1977; and in Ausubel *et al.*, 1978). No single theory of learning or learning hierarchy seems adequate to discriminate between all the types of cognitive tasks required of secondary students in science classrooms. Each theory or hierarchy provides some distinctions but fails to account satisfactorily for others perceived to be of importance. This accords with the conclusion reached by Bloom (1956), during the construction of the Taxonomy of Educational Objectives - Cognitive Domain.

Members of the taxonomy group spent considerable time in attempting to find a psychological theory which would provide a sound basis for ordering the categories of the taxonomy. ... We were reluctantly forced to agree with Hilgard (1948) that each theory of learning accounts for some phenomena very well but is less adequate in accounting for others. What is needed is a larger synthetic theory of learning than at present seems to be available (p.17).

In the absence of one comprehensive theory, it has been necessary to draw threads from a range of theorists. Such an approach may be criticised on the grounds that 'we cannot legitimately work in the framework of one theory and then invoke principles and concepts that are derivative from another theoretical framework' (Novak in Tamir, 1980, p.152). Tamir's response to this criticism by Novak is relevant to the approach adopted here, particularly in the absence of a single, adequate theory. He says:

Perhaps when one deals with a highly formal discipline this (Novak's) argument is valid. Yet, even physicists find it possible to work simultaneously within the framework of two alternative theories, wave theory and particle theory. Education ... is a practical discipline, much richer than only one theory can encompass. The art of the eclectic is the one that helps educators in seeking and obtaining the best guidance in each particular event (p.152).

WHAT DETERMINES COGNITIVE DEMAND?

Several features of a task contribute to the demands that it makes on pupils. In the absence of a single, adequate theory of learning, how is it possible to discriminate between all the cognitive tasks encountered in secondary science classrooms, in terms of cognitive demand? What is the effect of differences between tasks on their cognitive demand?

Four dimensions of cognitive demand emerged from the available learning theories and hierarchies to provide a basis for such specific discrimination between the demands of cognitive tasks. The four dimensions are:

- (i) complexity - the nature of the sequence of operations which constitutes a task, that is, the nature of each component operation and the links between operations;
- (ii) openness - the degree to which the learner is required to generate ideas;
- (iii) implicitness - the extent to which the learner is required to go beyond data available to the senses; and
- (iv) level of abstraction - the extent to which a task deals with ideas, rather than concrete objects or phenomena.

Cognitive demand is therefore defined as the demand which is placed on cognitive abilities, through the dimensions of complexity, openness, implicitness, and level of abstraction (Edwards and Dall'Alba, 1981). The way in which each dimension was derived from the relevant hierarchy or theories will be explained in the remainder of this section. Some dimensions of cognitive demand can be readily distilled from their original source, while others require extending or adapting the ideas advanced by the theorists.

Complexity

Bloom's Taxonomy (Bloom, 1956) provides guidelines for isolating and clarifying the cognitive operations which a task requires. Cognitive operations are those subordinate steps that rely on cognitive abilities and are linked together to comprise a task. The Taxonomy is useful in discriminating between tasks in terms of these cognitive operations. Analyses of tasks according to the Taxonomy reveal that it is concerned with complexity. It distinguishes between tasks according to the operations that they require and the way in which these are linked together for each task. The Taxonomy is based on the idea that 'a particular simple behavior may become integrated with other equally simple behaviours to form a more complex behavior' (Bloom, 1956, p.18). The categories are of the form A, AB, ABC, etc., where A, B, and C represent simple behaviours which become integrated to form more complex behaviours. Complexity may be defined as the nature of the sequence of operations which constitutes a task, that is, the nature of each component operation and the linkages between operations. Hence, complexity of a task may be represented by its position in Bloom's Taxonomy of Educational Objectives-Cognitive Domain.

Analysis of the relative complexity of tasks using Bloom's categories illustrates that the Taxonomy is useful but inadequate in distinguishing between tasks in terms of cognitive demand. Complexity is only one dimension of the concept of cognitive demand. Two items falling within the same level of Bloom's Taxonomy may be significantly different in terms of cognitive demand. For example, both of the following items may be classed as extrapolation (which falls within Bloom's 'comprehension' category), but they are not of similar cognitive demand:

- a) Students are shown the graph of a relationship which approximates a straight line. They are asked to make a prediction beyond the data given.
- b) Data are provided on the growth of a rabbit population, with information on food supply and space available. Students are asked to predict growth of the population for the next two breeding seasons.

In the latter example, the student is required to generate ideas in considering alternatives to a greater extent than in the former. Bloom *et al.* do not treat the issue of differential cognitive demand within a single category. In addition, regions of overlap exist between the Taxonomy categories. (This claim is supported by Furst, 1981.) According to Bloom's Taxonomy, 'synthesis' is more complex than 'analysis'. However, an item requiring comparatively low level synthesis may be of lower demand than a high level analysis item. For example, consider the following item which requires students to hypothesise (Bloom's 'synthesis'):

It is important that all bottle stoppers be placed in the correct containers immediately after use. What are the possible dangers if this procedure is not followed in the laboratory?

Compare the level of demand of the 'synthesis' item above, with that of the 'analysis' item below.

When an unknown gas is bubbled through clear lime water, Ca(OH)_2 , a white precipitate forms. It is concluded that the gas is carbon dioxide. On what assumption is this conclusion based?

The former example is less demanding, since it may be more readily and directly related to the student's experience and has less emphasis on generation of abstract ideas. Since complexity does not alone account for cognitive demand, Bloom's Taxonomy is inadequate as the sole basis for distinguishing between tasks in terms of the cognitive demands that they make.

Openness

In the previous examples relating to complexity, distinctions were made in terms of the extent to which the student is required to generate ideas. de Bono (1976) refers to active thinking which requires the generation of knowledge as 'generative'. The extent to which a task requires generative thinking can be expected to influence its nature and cognitive demand. Provided other factors remain constant, a task which is highly generative demands thinking of a higher order than one which concerns only the information that is given.

Taba distinguishes between 'what is "given" to the student and what cognitive operations he is asked to perform' (Taba, 1962, p.117). Two tasks may be similar except that in one instance the information to be operated on is supplied, while in the other it is not. For example, the student may be asked to classify some objects or organisms according to given criteria or, alternatively, to design an appropriate classification scheme, then use it to classify the objects. Where the criteria are not supplied, the student must perform more operations, and of a more demanding type, to generate the information before the task can be completed.

Integration of Taba's distinction between what is 'given' and the cognitive operations required, with de Bono's 'generative thinking' points to the dimension of openness, that is, the degree to which the learner is required to generate ideas. Neither theorist relates openness to cognitive demand in the sources reviewed. However, if other factors remain constant, increasing openness would be expected to increase cognitive demand. In isolation, however, openness is insufficient as an indicator of cognitive demand. The same information may be supplied for two tasks which require the learner to employ distinctly different cognitive operations. For example, the learner may be given a statement of a rule and, on the one hand, be asked to apply it, while on another occasion, be asked to explain its meaning. Although they have a common knowledge base, these tasks differ in cognitive demand. In such cases, other dimensions of cognitive demand override the effect of openness. Hence, openness is only one of several dimensions of the concept of cognitive demand.

Implicitness

The third dimension of cognitive demand, implicitness, is concerned with the extent to which the learner is required to go beyond data available to the senses. This dimension was isolated following reading of studies of cognitive growth by Bruner et al. (1966). Cognitive growth is said to be reflected by progression from a focus on explicit properties or 'surface sensory properties' (Bruner, 1966, p.322) to properties which are implicit, such as 'functional significance' (Olver and Rigney Hornsby, 1966, p.78) and common 'linguistic classifiability' (Bruner, 1966, p.322). Since the recognition of implicit properties occurs at a later stage of development, it reflects a higher level of cognitive growth. It may be inferred that such increased cognitive abilities indicate that awareness of implicit properties is of a higher order of cognitive demand than solely recognising perceptible or explicit properties. Hence, the cognitive demand of a task increases with the extent to which the properties are implicit, rather than readily perceptible. Consider the following example:

Weigh a clean, dry crucible and lid containing some magnesium.
Place the crucible on a pipe-clay triangle in a tripod stand and heat it, lifting the lid slightly with a pair of tongs to admit air.
When the magnesium burns, take care to prevent loss of any of the magnesium oxide formed. When the action is complete, allow the crucible to cool, and reweigh it. It will now be heavier than before.

Can you explain this? (Barrell, 1973, p.128)

In answering this question, the student cannot rely solely on observation. The task requires the processing and synthesising of information which goes beyond the data that are available to the senses.

The studies by Bruner *et al.* (1966) are primarily concerned with growth in young children. Implicitness tends, therefore, to be of greatest importance in distinguishing less demanding tasks. For tasks of higher demand, the effects of other dimensions of cognitive demand often outweigh implicitness. In the example above, the openness and abstractness of the task are at a higher level than its implicitness. The openness and abstractness raise the overall demand of the task.

Level of abstraction

The fourth dimension of cognitive demand arises from the need to distinguish between tasks according to their contexts. If a learner is working with objects that are physically present, the cognitive demand of such a task will differ from that of an operation which relates solely to ideas. Piaget (as interpreted by Novak, 1977; ASEP, 1974; and Karplus, 1977) discusses the changing capacity to cope with abstraction as cognitive development progresses. At the secondary school level, cognitive development is characterized by a shift from reliance on 'concrete empirical props' (Novak, 1977, p.121) to dealing "internally" with ideas about ideas' (p.122) - the abstract. Piaget's theory has been criticised on the grounds that his stages suggest saltatory rather than smooth development (Boyle, 1969; Ausubel *et al.*, 1978). However, his contributions regarding the distinction between concrete and abstract levels of reasoning may be treated outside the stage concept (Karplus, 1977; Ausubel *et al.*, 1978). This study has drawn on the levels of abstraction characteristic of the stages, rather than the stages themselves. Consideration of the level of abstraction contributes to the concept of cognitive demand primarily in distinguishing between tasks of unlike contexts.

As with the second and third dimensions, there are no direct claims put forward by Piaget relating to cognitive demand, in the literature reviewed. He does, however, align ability to handle abstractions with the highest level of cognitive development and emphasises that each stage is built on the preceding one (Novak, 1977, p.123). It would be expected, then, that with progression from concrete to abstract levels of cognition, cognitive demand increases.

The Parts and the Whole

The demand of any single cognitive task can be determined by the interaction of its complexity, openness, implicitness and level of abstraction. For any single task, the contributions of each dimension to cognitive demand are seldom equal. One dimension may have a disproportionate influence and largely outweigh the effects of the others. For example, a task may be relatively low on openness, implicitness, and level of abstraction, and yet be very complex. In such instances, the dimension of the

highest level is the principal factor for determining the level of cognitive demand. However, the remaining dimensions may lower the cognitive demand level, so it is not sufficient to consider only the highest dimension. For example, students may be given a task which requires applying a principle. Suppose the task involves direct application of a principle which is given. The level of cognitive demand of the task is lowered by its context (the lack of openness and low level of abstraction). This may be contrasted with application of an abstract principle. In the latter case, the abstractness of the task raises the level of cognitive demand. Thus, the level of cognitive demand of a task is determined by the interaction of all of its dimensions. One way in which these dimensions can be integrated to form a scale of cognitive demand for secondary science is described by Edwards and Dall'Alba (1981).

In summary, highly demanding and less demanding cognitive tasks in secondary science differ in identifiable ways. The cognitive demand of a task is dependent upon its complexity, openness, implicitness, and level of abstraction. These dimensions are not discrete, they are interacting and overlapping. No one dimension allows discrimination that is comprehensive and yet sufficiently specific. However, interaction of the four dimensions permits such discrimination. Whilst the dimension requiring the highest level of cognitive demand is the principal factor in determining the overall cognitive demand of a task, the remaining dimensions may create a context that lowers the cognitive demand level.

IMPLICATIONS FOR THE SCIENCE CURRICULUM

The concept of cognitive demand as described in this paper has direct application to secondary science lessons, programs and materials. It may be used:

- (1) to reveal the extent to which the demands of objectives, learning tasks and evaluation items are internally consistent for lesson plans, programs, texts, and other materials;
- (2) in lesson planning, to clarify what is required of the student;
- (3) in program evaluation, to expose the relative emphases on cognitive skills;
- (4) in school-based materials development, so that the cognitive demands actually made by the materials can be compared with those intended by the materials developer, at the pre-trial stage; and
- (5) in formulation of clear objectives, by clarifying the breadth and depth of treatment implied by those objectives.

FUTURE RESEARCH

This paper has focussed on the inherent cognitive demand of a task. This demand can be contrasted with the way in which a student attempts to complete the task. It is possible to determine the cognitive demand of the steps which a student takes and to examine whether the task is completed at the same level as that intended. Similarly, a teacher may supply additional information to particular students who are experiencing difficulty. In so doing, the teacher can lower the openness of the task and hence decrease its demand. Those students would then be able to complete the task at a lower level of demand. A comparison of the inherent cognitive demand of a task with that of its completion in practice would seem to be a logical extension of the work in this paper. It may help to isolate one of the difficulties many students encounter with secondary science programs.

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INVESTIGATING LEARNING IN SCIENCE AT THE PRIMARY SCHOOL LEVEL

Fred Biddulph, Roger Osborne, and Peter Freyberg

BACKGROUND

From February 1979 until January 1982 a government funded research program, the Learning in Science Project, was based at the University of Waikato. The Project investigated some of the difficulties of teaching and learning science at the F.1-4 (approximately 11-14 year old) level and explored ways of overcoming some of the key difficulties. The main findings of that Project were described by Osborne and Freyberg (1982) who also referenced 54 of the Working Papers and many of the published papers which resulted from the research.

In February 1982 a new investigation, the Learning in Science Project (Primary), commenced at the University of Waikato. This is a similar three-year study of the teaching and learning of science, but at the S.2-4 (approximately 8-11 year old) level. This paper summarises the work undertaken, and the findings obtained, during the first 14 months of the new Project.

EXPLORING THE DIFFICULTIES

In the first six months of the Project an exploratory phase, similar in nature to the exploratory phase of the original Learning in Science Project, was undertaken. Almost one hundred inspectors, teachers' college science staff, science advisers, principals, teachers, and pupils were interviewed about, and commented on, their experience of the teaching and learning of science at the Standard 2-4 level. Using a grounded theory approach (Glaser and Strauss, 1967) the perceived difficulties were isolated and reported by Biddulph (1982a). In addition a range of lessons was observed and pupils and teachers were talked to in the classroom setting. Findings from this work were also reported by Biddulph (1982b).

Biddulph (1982a) found that a substantial number of the people interviewed thought that many teachers tend to avoid teaching science. Those interviewed considered that when science is taught it is frequently teacher-dominated, children's ideas tend to be ignored, and a genuine spirit of inquiry is frequently not encouraged. Examples quoted include,

They [teachers] only ask questions when they know the answers exactly and if they do not get the answers they will keep nodding and looking until they get the answer they want and the words they want.

and

I tend to think that there are a lot of teachers who would stifle questions in a way to suit themselves rather than the children. (Primary inspector)

The reported experiences of pupils reinforce the view that the difficulties outlined are important ones. While science is undoubtedly enjoyed by children when they experience new activities and learn new things, they do not enjoy what they perceive as too much teacher's talk, too much writing, too much repetition of topics and situations in which they do not understand words and ideas (Biddulph, 1982a).

Observations of lessons reinforced many of the interview statements (Biddulph, 1982b). Particular difficulties with activity-based work were observed; the problem to be investigated, the procedure for solving the problem and often the conclusion to be drawn from the experience tended all to be teacher-dominated. As Tasker (1981) found at the Form 1-4 level, the teacher's problem often does not become the pupils' problem, the procedure suggested for solving the problem is not fully appreciated, and little notice is often taken of a pupil's own conclusions. Pupils often do things, learn things and have problems of which teachers are unaware; they translate instructions into unanticipated actions, they often play games with the teacher to find the right answer that the teacher requires, and they copy the teacher's conclusions from blackboard to book with no real appreciation of how those words relate to what they found out themselves. As one pupil stated, 'You just do it to please the teacher'.

The findings of all this work tended to confirm that many of the difficulties isolated in the Form 1-4 Learning in Science Project, and described in Tasker, Freyberg, and Osborne (1982), also exist at the Standard 2-4 level. The work undertaken in both Projects, in addition to other work undertaken in this country and overseas, suggests the main difficulties include:

i) Teacher Background: Teachers lack confidence in science teaching, mostly because they consider that they have a personal lack of science knowledge and experience in science inquiry. This is a major difficulty, certainly not unique to New Zealand, which needs to be overcome if the potential of teachers is to be harnessed in effective primary science teaching.

ii) Practical Difficulties: While many teachers appreciate the specific guidance provided by the available resource units, there remain practical and organisational difficulties which limit teachers' confidence and limit the amount of science that is

taught. There are significant difficulties in storing, organising and setting out equipment and materials. There are difficulties in focussing pupil attention, of ensuring that pupils use the equipment in anticipated and desired ways, and in coping with the questions raised by children as they attempt to integrate new experiences into their way of thinking about the world.

iii) Aims of Science Education: Many primary teachers do not have a conviction that science is an essential and important area of the curriculum. Associated with this, there are divergent views about the aim of science in the primary school. While some argue that primary science should develop skills to solve problems in a 'scientific way', the actions of many teachers in the classroom suggest that either science teaching is considered to involve getting across a body of scientific knowledge to children or that science teaching is simply a vehicle for vocabulary extension. Teachers may well adopt certain aims for science teaching as a way of rationalizing in their own minds why some of the practical difficulties associated with their own lack of knowledge or confidence need not be faced.

In addition to the above findings, other findings from the original Learning in Science Project also have a number of implications for Primary Science. In that project children's views of the world and meanings for words were explored at all age levels. The present research has confirmed that,

- i) children have views about a variety of topics in science from a young age and prior to learning formal science;
- ii) children's views are often different to scientists' views, they are frequently not well known, and to children they are sensible and useful views; and
- iii) children's views can remain uninfluenced, or be influenced in unanticipated ways, by science teaching.

In this exploratory work we have concentrated on the difficulties of primary science teaching. We have not attempted to evaluate primary school science, nor to provide a balanced view of the good and bad aspects of this science teaching. The difficulties we have isolated are not unique to the primary level of education, to New Zealand, or even to science education. As Barnes (1976) comments from his studies across the curriculum in the U.K.

Pupils conform, and even play the system, but many do not allow the knowledge presented to them to make any deep impact upon their view of reality. (p.17)

A PERSPECTIVE ON PRIMARY SCIENCE

It became apparent during the exploratory phase that what was meant by 'science' at the primary level was not as obvious as might be thought. There was a divergence

of opinion about the relative importance of influencing children's concepts, process skills, and attitudes not only amongst teachers but also amongst science educators, both nationally and internationally. To enable us to clearly identify and to proceed to overcome some of the difficulties isolated in the exploratory phase of the Project, we the researchers first needed to consider what we meant by 'primary science'. Accordingly, after considerable deliberation, a particular perspective was adopted (Symington, Osborne, Freyberg, & White, 1982). Briefly, this is that primary science should encourage and enable children to ask questions of, to do things with, and to think about and discuss aspects of their natural and technological world in ways that will help them make better sense of their world. With respect to explanations as to why certain things behave as they do, primary science should help children to appreciate explanations different from their own and to appreciate in what ways some of these explanations may be more useful than their own current ones.

In addition, it was considered that primary science programs should be constructed in a way that would enable teachers to grow in confidence through helping them to better understand, predict, and control events in their classroom. If the programs for teaching science do not help the teacher in these ways then science will not be taught in primary schools.

These ideas about primary science were 'reflected' off a range of people involved in primary science and curriculum development. The reaction of those consulted was supportive and suggested that the perspective adopted could be useful to the Project.

Implications

The perspective on primary science outlined above has implications for teaching and learning. Topics need to be chosen which are of interest to children; concepts need to be focussed on which will help children understand everyday phenomena, and which are within their grasp; children need time to explore and do things within particular situations; children need to be encouraged to ask questions and to form explanations; children need to be encouraged to consider alternative explanations and be ready to change their ideas; children need to be involved in carrying out investigations of questions, and of alternative explanations, which are relevant to them; children should be helped to develop those investigatory skills which will enable them to effectively obtain useful answers to their questions, and children should begin to appreciate the kinds of questions, explanations, and investigatory procedures of interest to scientists. These implications are explored further in Symington et al. (1982) and Osborne et al. (1982).

There is nothing radical about the above suggestions. The continuing problem is to find a way whereby these ideals may be achieved in practice.

PROCEDURES FOR GATHERING INFORMATION ABOUT CHILDREN'S INTERESTS, IDEAS, AND SKILLS

Following some exploratory work in classrooms by Project members, procedures by which the Project team could obtain information about children's interests, ideas, and skills with respect to various science topics were spelled out (Symington, Osborne, Biddulph, and Freyberg, 1982). It was later realised that the procedures could form the basis of an alternative approach to science teaching (Biddulph and Osborne, 1982; Biddulph, Osborne, and Freyberg, 1983) that had the potential of guiding teachers towards the perspective mentioned above. This alternative teaching approach is outlined in Appendix I.

Research Plan

Initial experiences by both teachers and Project team members using the research procedures pointed to the possibility of a modular research plan being formulated (Biddulph, Osborne, and Freyberg, 1983). The framework on which each module of research could be planned is reproduced below as Figure 1. This modular approach allows flexibility but enables various individuals and groups to be involved in research in a co-ordinated way.

To summarise, the plan requires that information be obtained about:

- i) children's ideas with respect to key words and various topics, e.g., metal, food (Phase 1);
- ii) children's questions and explanations, and the status that they accord those questions and explanations, such as to be obtained from children both individually and in groups, and perhaps later via surveys (Phase 2);
- iii) factors that enable teachers to make use of the alternative science teaching approach, or factors that inhibit them in its use, including the level of research skills that children bring to the task (Phase 3); and
- iv) the type of format of guide materials that would provide teachers with the support that they feel they need in order to teach science using the alternative teaching approach or a modification of it (Phase 4).

Which Topics Should be the Focus of Our Research?

An earlier paper (Biddulph, Osborne, and Freyberg, 1983) considered in some detail which topics should be the focus of research and concluded that both 'popular' topics and topics which are considered more difficult should be investigated, provided that they are 'close to children' in the sense that they are part of, or capable of being part of, the children's immediate world, and that they are topics about which children can form real understandings. We would now add the emphasis that we are particularly concerned with topics that can provide children with understandings basic to the development of later scientific ideas.

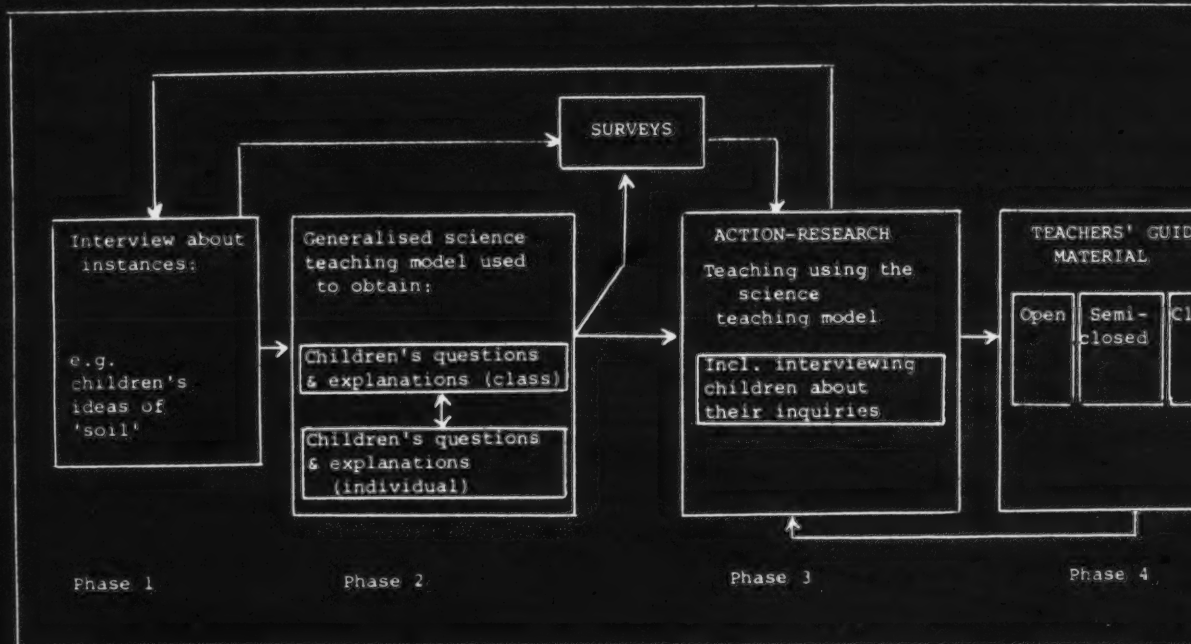


FIGURE 1

Primary science research plan 1981-84

Preliminary Investigations

During the planning of the research program for the next two years we have also undertaken a range of preliminary investigations. These are partly discussed in Symington, Osborne, Biddulph, and Freyberg (1982). The investigations and preliminary results from this work include:

- (a) What topics are children most interested in? Survey investigations, contrasted with contrived classroom work, suggest to us that children's interest in a topic is likely to be more dependent on the particular way the topic is introduced than on the children's perceived view of the general topic.
- (b) What questions do children ask in a given situation? Classroom observations suggest to us that children ask questions only about the natural and technological worlds in the course of a normal lesson. However, if they are specifically asked to generate questions with respect to a particular situation they will do so. Furthermore when children ask questions this stimulates other questions from other children. There are common questions across classrooms and even across countries.
- (c) Which of the questions are of greatest interest to children? Given a set of questions the class has generated, the children regard some questions to be of more interest than others. So far our experience suggests that the questions children are interested in are not always the focus of presently available resource units. For example, a resource unit on 'Wood' focusses on flexibility and hardness while children appear to be more interested in how the rings were formed, the purpose of bark, and so on (Symington, Osborne, Biddulph, and Freyberg, 1982).
- (d) What explanations or answers do children generate? Once a class has generated a set of questions, and chosen those questions they find most interesting, we have asked them to suggest answers to the questions. Children are never short of answers! Furthermore their answers give insights into the way they perceive the questions. They also show how pupils provide a range of explanations that are scientifically acceptable as well as many explanations which are not the province of scientific endeavour and interest. Examples of non-scientific type explanations are: 'a tree has bark to make it look pretty', 'a tree has bark because God made it like that'. The recognition that a range of answers may be scientifically acceptable is important as teachers often focus on what they consider to be the one acceptable scientific answer.
- (e) What methods do children tend to suggest to check on an answer? Some recent science programs have focussed exclusively on questions which can be investigated by children using hands-on enquiry. Where such questions occur this type of investigation would appear to be particularly desirable. However our experience so far is that children ask many questions which are non-investigable through hands-on enquiry and our view is that children should attempt to find answers to such questions. Children are interested in asking people, whom they consider might know the answer, what they think. Children also suggest that reference books should be

consulted. Scientists also tend to use similar strategies to find answers to their problems!

(f) How successful are children in establishing the validity of answers to questions? At present we are exploring this question. We have to accept that children may often be unsuccessful - so are scientists. Pursuing this approach to science teaching may lead to children being able to distinguish between questions to which they can or cannot obtain answers. This, in itself, is a major scientific skill.

(g) How practical are our views on primary science and how acceptable are our views about the importance of focussing on children's questions and explanations? Many of our preliminary investigations have been undertaken either by classroom teachers or with the classroom teacher and others observing our work. We have been encouraged by teacher comment. In particular we have noted teachers' interest in learning about children's questions and explanations, and their surprise at the sophistication of these. Some teachers have been encouraged through their observations of our work to find out children's ideas on other topics. The focus on the children, with less focus on imparting science knowledge, would appear to find considerable favour with the primary teacher.

WHERE TO FROM HERE?

In this paper we have set out the implications from our earlier research, and from our thinking about primary science, in terms of a set of research tasks. Our recent preliminary investigations of some of these research questions, and teachers' reaction to the work, encourages us to proceed with these tasks. What is clear to us, at present, is that we will use a range of procedures including individual and group interviews, classroom teaching experiments, and classroom observational techniques. Moreover, mindful that our most important audience for the research outcomes are practising classroom teachers, we will continue to involve them in the research at all levels.

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APPENDIX I

The Primary Science Teaching Model Under Investigation

- Step 1: CHILDREN IN INTERESTING SITUATION.
A situation that stimulates the children to ask questions related to a science topic.
- Step 2: CHILDREN'S QUESTIONS ON THE TOPIC
These could be publicly recorded, e.g., on the board.
- Step 3: CHILDREN'S SUGGESTED ANSWERS TO A QUESTION
These could be written on paper by the children either individually or in groups and if desired then also listed on the board.
- Step 4: CHILDREN'S RESEARCH PROPOSALS
At this step the children either individually or in groups write a research proposal outlining:
- (a) the question/answer they are going to check on;
 - (b) how they are going to check on it;
 - (c) where they are going to check on it;
 - (d) how long they estimate they will take;
 - (e) what equipment they will need.
- Teacher approval will be necessary before children embark on Step 5. (A teacher may decide to accept some proposals that are doomed to failure but from which children will learn something useful.)
- Step 5: CHILDREN'S RESEARCH ACTIVITY
The children conduct an inquiry on their problem using their suggested activity. This may be
- (a) observation or 'experiment';
 - (b) consulting books;
 - (c) consulting knowledgeable people.
- Step 6: CHILDREN'S RESEARCH REPORT AND PEER COMMENTS
The children report their findings to the rest of the class.
The other children, with teacher guidance, comment on
- (a) whether or not the group or individual had really found out what they were trying to find out;
 - (b) possible alternative explanations;
 - (c) other studies that might follow.

TRACING THE ORIGINS AND DEVELOPMENT OF THE MODERN SCIENCE TEXT: ARE NEW TEXT BOOKS REALLY NEW?

Paddy Lynch and Paul Strube

INTRODUCTION

In attempting to understand the effects of textbook language on learning, and the role of textbooks in fulfilling the aims of education, it is important to trace, however generally, the development of their style of presentation with time. This study is concerned with physical science texts from about 1820 to 1900. From reading several hundred it is apparent that many of the structural, linguistic, and stylistic characteristics of today's texts have their origins in 19th century science writing. Furthermore, the earlier texts can be examined for alternative approaches to textbook language and style, and to science education.

The science textbook did not suddenly appear fullblown in 1800. Science writing for scholars can be traced to the medieval period, and ultimately to fragments abstracted from the Greek natural philosophers. But science writing which was meant for children only became widely available in the 19th century. This development yields a working definition of a textbook as any written material designed to inform and be used in schools. This type of wide definition is useful since it includes material written specifically for schools, and works which are often called 'popularizations' and which at the time were taken into the schoolroom because nothing more suitable was available. Compulsory education did not begin in earnest in England until 1886 and writers who wanted to give all children access to science could not assume they would be at school. It was their writings which teachers used in various ways. In the following discussion only English science texts will be considered since they became models for texts written in Commonwealth countries, and were the only ones available at the time.

From our study of texts we have been able to identify four main types referred to as Catechetical, Conversational, Experimentalist, and Formalist. The historical relationship between the four is not linear: indeed, each grew out of its own set of influences, not quite independently of each other, but distinct enough to make a linear relationship difficult to justify. The separate influences will be considered as each type is discussed in turn, but it is also helpful to use a time-line to indicate the rough chronological relationship between them. Figure 1 shows this relationship and

implies that it may be more appropriate to speak about the background influences of the modern text rather than its development. All four types of text influenced science education in schools, because many of them were written by prominent educationalists concerned with the place of science in the curriculum (Layton, 1973).

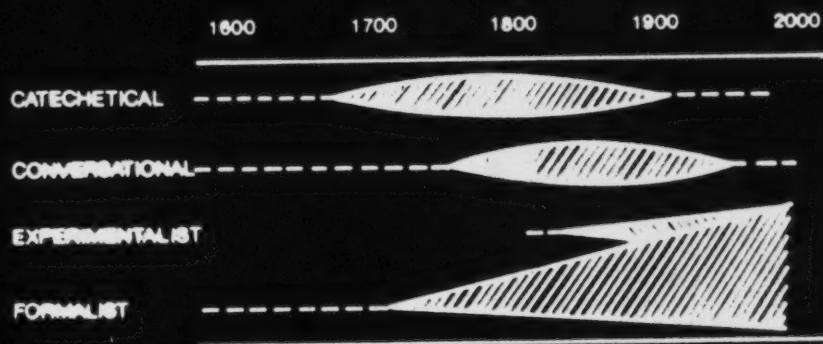


FIGURE 1
Test Development versus Time

THE CATECHETICAL TEXTS

The catechetical texts are in question-and-answer form. This suggests they may have their origins in the type of Socratic dialogue familiar to many medieval religious debates, and the dialogues of Galileo. Examples from Pinnock's Catechisms of the Arts and Sciences (1822) follow. Pinnock covered an encyclopedic range of topics using small pamphlets which were sometimes bound together into collective volumes. His abstracts contain two essential characteristics of early catechisms; a strong religious content, and simple reasoning from common experience without reliance on experiment..

Q What is meant to be absolute motion?

A That which is measured with regard to an object at absolute rest, or where the space passed over is absolute space, - that which contains the whole universe, and which therefore cannot move.

Q Cannot we measure or estimate a motion of this kind?

A No; because we are not sure that any body is absolutely at rest. The water moves; the air moves; the earth moves; the moon and planets move; we know from the appearance and disappearance of the same spots on the disc, or face, of the sun, that the sun moves round an axis.

Q Is not that taking rather too extended a view of the works of nature?

A The wonders of creation are limited only by the power of their CREATOR, and that is far beyond what our observation, or even our imagination, can survey. System may be joined to system, and constellation after constellation of systems may revolve round centres more powerful and roll in orbits more immense. (p.51-52)

Q Whence do those variations and changes of motions proceed?

A They are usually said to proceed from differences of FORCE.

Q What do you mean by force?

A Any phenomenon that is accompanied by change in the state of body, whether that change from rest, or from one direction of degree of motion to another, is said to be produced by a force. We say, the force of wind; the force of fire; the force of gunpowder; the force of a blow; and we never see any thing in motion without thinking of the force that made it move.

Q Are force and motion the same then? (p.53)

Now Pinnock's type of text has a certain appeal to the rote-learning school of pedagogy. Another, by Brewer (1855) contains an index, and 106 unanswered questions 'for the ingenious reader to solve'. This latter type is a forerunner of the texts with the ubiquitous 'questions-at-the-end-of-the-chapter' format. Note that the catechisms were text, resource, moral and ethical reader and dictionary all in one and for the writers, science had a role to play in the moral as well as intellectual growth of the child. The world is carefully arranged in accordance with God's plan, and the emphasis on the practical uses of nature as revealed by the questions and answers hints that man is expected to use nature to advance himself. These early texts contain little theory or discussion of the ways knowledge is uncovered by science. They are not speculative, asking their readers to enquire into the subject any further. Their direct concern was to offer simple explanations for common phenomena. These explanations, however, were concerned only with phenomena. Any questions of meaning usually introduced God into the discussion. It was thus well established that textbooks should consider what things do rather than what they are.

The view of science as a human activity that these texts implicitly convey is that of a rational pursuit of natural Truth. It is also, more explicitly, a vehicle for the admiration of God. There is the view of the world operating by virtue of the laws of motion and change implanted in them, once only, by God. Science, therefore, served a purpose greater than itself.

THE CONVERSATIONAL TEXTS

The conversational texts are very different in format to the catechetical. Here is an example:

Conversation IV

The Planet Venus

Early the next morning, the children saw their papa walking in the garden alone, and they ran down from the nursery to ask for the history of another planet before breakfast. Their papa began thus: 'Next to Mercury comes Venus, the most beautiful of all the planets, and the brightest that can be seen from the earth. Our great poet Milton thus speaks of her:

'fairest of the stars, last of the train of night,
If better thou belong not to the dawn,
Sure pledge of day, that crown'st the smiling morn.
Why thy bright circlet?'

'Why does he speak of Venus as crowning the smiling morn? Does it ever shine in the morning?' asked Henry. 'Venus, in one part of her course is seen for more than three hours before sunrise, and in another for as long after sunset: this is why ...' (Tomlinson, 1870, p.37)

This illustrates a tendency to adapt pages to school use. Important terms were often italicized, and defined in the course of conversation. Often, a conversation was accompanied by a table of data, and there was a quotation from Milton to express a belief that all knowledge could indeed be harmonious within the mind of the educated man. To be truly educated was to see and note such relationships, and by inference, they had a rational unity.

A second example comes from the Rollo Series (1855) volume on AIR. Actually there are fourteen volumes in the series, dealing with reading, travel, correspondence, and natural philosophy - Air, Water, Fire, and Sky.

Rollo seemed to be very much interested in this conversation. He had dismounted from his father's knee, and stood by his side, listening eagerly. His mother, too, was paying close attention. As for Nathan, he sat still; though it is not by any means certain that he understood it very well. 'Let us suppose', said his father, 'that the mass of lead, as big as a load of hay, is fastened to one end of a stick of timber'. 'That would not be strong enough to hold it', said Rollo. 'Well, then, to a beam of iron, as large as a stick of timber', rejoined his father. 'O', said James, 'you could not get such a big bar of iron'.

'No', replied his father, 'only an imaginary one; and that will be just as good as any. Now, suppose the great mass of lead is fastened to one end of this bar, and another one, just like it, to the other end, to balance it. Now suppose that the lower end ...'

Rollo began to laugh aloud at this idea, and looked very much interested and pleased. 'O, then I wish there was no gravitation', said Rollo; 'I do, really'.

'But, then', continued his father, 'if you should get up into the air, you could not get down again'. 'Why not?' said Nathan, beginning to look a little concerned. 'Unless', said his father, 'you had something above you, to push against, so as to push yourselves down. You would be just a boy in a boat, off from the shore, and without any paddle or pole. He could not get back again'. 'We might tie a rope to something', said James, 'before we went up, and so pull ourselves down'. (p.148)

This rather lengthy selection is interesting because it illustrates the way science can be taught without practical work - by story telling, illustrated by objects of common experiences. As these texts were taken up by teachers in schools, questions were included at the end of each conversation. These questions are comprehension type questions rather than questions of fact (i.e., 'Why did the boys wish there was no gravitation?')

It is difficult to see many traces of these conversational readers in today's textbooks. Indeed, their greatest interest lies in their contrast. The explanations take place within a discourse, and are based on drawing and analogies from common life. Like the catechisms, they are nominalistic. The style presents science with a very human face - the student has someone with whom to sympathize, and learns indirectly. These texts still reveal science in education as part of a means-end relationship; science is simply one means of producing an educated, rational, moral adult. It would be interesting to know how the books were actually used by teachers in schools, and whether they were strictly fact-oriented in their approach. The age of the children who used the books is not known. Today these narrative forms are regarded as suitable for the primary grades only where content is secondary to comprehension. In the formalist texts to be examined subsequently, this is reversed; comprehension is of high priority; though what counts as comprehension changes dramatically.

THE EXPERIMENTALIST TEXTS

The Experimentalist text was originally associated with the heuristic movement, towards the end of the nineteenth century. This movement stressed the importance of enquiry oriented teaching that emphasized observation and experiment.

The textbook was an anathema for the 'heurists'. They feared the 'domination of a book which represented the antithesis of the open-ended enquiry teaching they were recommending. But some written model was necessary. A set of 'science primers' was published in the mid- to late 1870s by McMillans to meet professional demands. They became extremely popular, were used for more than 40 years in English and Commonwealth schools, an extraordinary long lifetime, and gave rise to a number of derivative texts. One of the most influential was Roscoe's (1872) Chemistry and the following abstract is taken from the 1913 edition:

FIRE I.

2. What happens when a candle or a taper burns?

The wax as well as the wick of the taper gradually disappears as the taper burns, and at last all is gone - wick, wax, and all. What has become of the wax? It has disappeared. Is it lost? So far as our eyes are concerned certainly it is lost but so is the ship which sails away on the sea, and yet we know that the ship still exists though we do not see it; and so the lump of sugar appears to be lost when we put it into a cup of hot tea, and yet we know that the sugar is not really lost, because the tea is made sweet. Now we must look for the wax of our taper in another way; we must put a question to Nature for her to answer, and we shall always find that our question, if properly asked, is always clearly and certainly answered. We must make an Experiment, and if this is properly made we shall never fail in the end to get the information we want.

EXPERIMENT 1 - Let us burn our taper in a clean glass bottle with a narrow neck; after it has burnt for a few minutes we notice that the flame grows less, and in a short time the taper goes out. This is the first thing we have to observe. We next have to discover why the taper goes out. For this purpose let us see whether the air in the bottle is now the same as it was before the candle was burnt. How can we tell this? Let us pour some lime-water (p.10-11)

The commitment to 'observing and experimenting' is maintained throughout the book where science in general, and chemistry in particular, is seen as a process in which careful attention to what happens in an experiment yields unexpected and most revealing truths. The teacher's task is to maintain the spirit of enquiry associated with evidence gathering and argument based on evidence, in that order. The book, of 96 pages, covers a lot of ground, and contains many illustrations for the experiments, the majority of which focus on everyday phenomena. The content is ordered into the divisions fire, earth, atmosphere, water, etc. - divisions which would be consistent with the student's view of the apparent structure of nature, unlike the divisions in many modern texts which force the scientist's world view immediately on the new learner. By and large the book is 'well thought-out', with a very clear rationale. In spite of this the publication, though popular, was by all accounts misused and like other texts was subject to a considerable amount of criticism in later years. Ironically, students were required to 'learn' the text chapter by chapter - quite the opposite of what was intended!

Yet this particular text which is definitive in style represents a complete break from the catechetical form: conversational dialogues too are de-emphasized in favour of the experiment itself.

THE FORMALIST TEXTS

The Formalist texts originated to make 'hard' science accessible to the masses. They represent the first attempts to distill and simplify the great classics of science for example, Newton's Principia, the works of Dalton, Lavoisier, and Laplace. The danger in attempting to do so was realized by J.W. Warren (1965), who suggested that many textbooks misinterpret Newton in their efforts to simplify his genius. Leaving that aside, the formalist texts were designed to be used for teaching science as a subject in schools. They are not popularizations but instruments of school-based instruction. Their character derives from a set of constraints which must be considered when the books are examined. Briefly these constraints were:

- 1 the developing nature of science as a discipline, which was beginning to exhibit the characteristics of objectivity, quantification, empiricism, and analytical reasoning. These features appeared in the texts;
- 2 the decline of ulterior religious purposes which, in general, are totally absent from the texts;
- 3 the increasing demand for the training of scientists and engineers so much so that science began to play an instrumentalist role in education;

- 4 the development of science as a school subject, which brought pressures on it from teachers, practical methodology, large classroom numbers, and the conflicting views of educationalists;
- 5 the lack of suitably trained science teachers, which meant that texts took a central role in the teaching of science, even though there was, as yet, no clearly formulated rationale for science education;
- 6 the influence of external exams.

Together these features shaped the major purposes of the texts which generally only varied in the formats. Some of the influences mentioned above were affecting authors as is illustrated in the following extract from the Preface to Hugo Reid's Elements of Astronomy (1842).

... it is extremely desirable that science should be introduced as a regular art of education into all schools, and that for this purpose there should be text-books composed of its various branches to aid the pupil; it being found that the most rapid progress is made when a lesson is given out to be studied by the learner, on which he is afterwards to be examined by his teacher.

Of the various sections of Natural Philosophy, no one seems better adapted for the instruction of youth than ASTRONOMY. The phenomena it describes are interesting above all others from their grandeur as well as from their practical application to the uses of human life; while, by the exactness of its laws and the certainty of its demonstrations, it is eminently fitted to improve the mind in precision of thought and accuracy of expression.

The passage reveals a view of science education as a 'means of mental discipline and intellectual improvement'. Also, there is a sketchy reference to learning theory expressed by the statement that 'the most rapid progress is made when a lesson is given out to be studied by the learner, on which he is afterwards to be examined by the teacher'. The format was designed to put information into 'short, aphoristic sentences, which will greatly assist the pupil in forming answers to the various questions that may be put to him by his tutor'. An example follows:

441. The mean distance of Saturn from the sun is nine hundred and four million miles (904,000,000). His eccentricity is more than 1-20th of his mean distance from the sun.

442. At Saturn, the sun will present a diameter about 1-10th of that seen at the earth. The proportion of the sun's influence which reaches Saturn is about 1-90th of that enjoyed at the earth - as 95^2 to 904^2 .

443. The equatorial diameter of Saturn is about 79,000 miles. The polar diameter of this planet is stated to be about 1-11th less than the equatorial. Having a very rapid rotation on its axis, it is to be expected that Saturn, like Jupiter, will be very much flattened at his poles.

444. Saturn rotates on his axis in 10 hours 16 minutes.

445. Saturn completes his revolution round the sun in 10,759 days, or about 29 1/2 years; - moving in his orbit at the rate of about 6 miles in a second, or 360 miles in a minute. (p.88)

There is no index or collection of questions in the volume which contains only information. It is impossible to know what a teacher would have done with this text beyond asking for memorizations and assigning homework readings. Nowhere are there appeals to the reader's imagination or religious sentiments so common in the previous material. The spirit of science is absent, its role in education and the life of the student completely unexamined. The whole notion of science as an exploratory activity is left untouched, not only in the sense that no accounts are given of how the information was obtained, or its gradual unfolding over time; but the whole idea of what counts as explanation in science is missing. Now many of these features have persisted over 150 years to influence today's texts. Consider too, the following excerpt from a later publication, Galbraith and Haughton's (1880) Manual of Hydrostatics, 3rd edition, one of a series of 12, concerned with either mathematics, engineering, or physical science. Its format resembles many 20th Century formalist texts; a bit of theory, description of apparatus, a formula or two, and some problems to work. There is no index, and no statement by authors of intent or theoretical position.

2. ...

3. A piece of beech weighs 63.48 grains; the weight of the compound body, using the same brass weight, is 776.29 grs.; find the specific gravity. $Sp.gr. = 0.853$.

5. Nicholson's Hydrometer. - A very useful instrument has been devised by Nicholson for ascertaining the weight and specific gravity of small substances ... Let S be the standard weight, W and W' the first and second weights; then -

$$Sp.gr. =$$

EXAMPLES

1. Let the standard weight be 300 grs.; calculate the specific gravity of a specimen of mineral whose first and second weighings give 25.36 grs. and 102.33 grs. $Sp.gr. = 3.568$.

2. Let the standard be 130.5 grs., and the first and second weights 20.20 grs. and 47.60 grs.: required the specific gravity. Sp.gr. = 4.025.
6. Specific Gravity Bottle. - This simple instrument, of which the adjoining figure represents a section, is equally useful in determining the specific gravities of solids and liquids. It consists of a thin glass bottle of a globular shape, and is generally made to contain either 500 or 1000 grains of distilled water at 60 F. ... (p.56,57).

CONCLUDING OBSERVATIONS

All four types of text represent a positive and determined effort to produce written forms suitable for the education of school students, yet the four different solutions to the problem represent extremes in underlying philosophy. The writers of the experimentalist texts emphasized experiential learning - experience of the phenomena in question being the key issue. All the other three types of text place a much heavier emphasis on language. The catechetical writers preferred a simple definitive response to key questions with no attempt being made to test depth of understanding. Curiously though, dictated notes given to students by teachers often come close to being catechetical in form and much teacher/student dialogue is in this vein, even though considerable attempts have been made to open up the scope of 'questioning'. One suspects, that, universally, catechetical learning is still very dominant.

The conversational texts stem from a Pestalozzian influence that of the object lesson in teaching. Today, the object lesson (the conversational dialogue using everyday objects) is considered to be somewhat passé but it represents an attempt to build a linguistic bridge between the scientist's world view and the child's world view - something which is still difficult to do. The conversational text has waned in popularity but still has much to recommend it, and it would not be surprising to see a modern day revival.

By comparison, the formal text makes little concession to the student's world view or perspective. The reader is presented with a simplified version of the scientist's world view but the treatises contain a level of abstract reasoning and a structure of argument that is much too demanding for the average student. The formalist text has a role to play but, on its own, is of limited value to the average student and appropriate only for the more able.

Finally, three findings appear to be of particular relevance to present day science teaching:

- 1 Much of the formal language, notable in what we have termed the formalist text, has scarcely changed in 100 years. Modern texts may be visually more attractive but many definitions and stylised arguments (i.e. much of the language) remain unchanged.
- 2 The modern text book seems to have combined the 19th Century experimentalist with the formalist text. Consequently it is often a large unwieldy inappropriate compendium whose sheer size must be daunting for the average student.
- 3 The various roles of language in science teaching were clearly developed in the early texts, but two of the early forms have virtually disappeared. The much maligned catechetical text resembles 'students notes' more than any other. Perhaps we should not condemn, but consider 'why?'. Likewise the mode of the demised conversational text deserves more attention as it may have special benefits for the average student.

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PROCESS SKILLS, CONCEPTS, AND NATIONAL ASSESSMENT IN SCIENCE

Wynne Harlen

It is eight years since I first became associated with the Assessment of Performance Unit (APU), as a member of a voluntary working party set up to consider whether it was feasible and worthwhile to assess scientific development of pupils in school and, if so, to give some operational meaning to this process. Two years with that working party, followed by six years as a full-time member of the research team carrying out the assessment, is a significant chunk of time. During that time science education has been under pressure to justify and account for its claim to be a basic part of the education of all pupils throughout the period of compulsory school attendance. My colleagues and I have been obliged to think very hard about what is worth assessing as well as about the process of assessment. We have given a great deal of prominence to assessing scientific process skills for reasons of their importance in science education. These reasons are put here within the context of the APU work, though I believe they hold outside that context equally well.

In this paper, then, I propose to discuss briefly the background to the APU work in science and the origin of the assessment framework and to use this as a peg on which to hang some ideas about the relationship between process skills and concepts. The discussion here concerns both secondary and primary science education.

First a word about the term 'process skills'. 'Process' is an overworked word in education and no longer conveys a definite meaning unless it is qualified. Therefore I use the term 'process skills' to mean the cognitive processes which describe various forms of interaction with content - observation, interpretation, inference, hypothesising, planning, etc. I defend the use of the word 'skill' on the grounds that I believe these process skills can be taught and do develop with practice, to some extent in the same way as physical skills. 'Process skills' refer to things that happen inside pupils' heads. 'Classroom processes' refer to actions and events which take place around pupils.

BACKGROUND TO THE APU SCIENCE PROJECT

The setting up of the APU was officially announced in 1974, though its roots went much further back. Its terms of reference are

To promote the development of methods of assessing and monitoring the achievement of children at school, and to seek to identify the incidence of under-achievement.

Thus it was conceived as a pupil assessment project; there was considerable initial resistance to assessing anything to do with teaching and total rejection of assessing relevant factors about pupils' home background. This resistance came not so much from the Unit itself, but from its major advisory body, the Consultative Committee, whose members are drawn from teachers' unions, local authority associations, and other interested organisations. There was a great deal of suspicion about the APU in its first few years and so the Unit was at pains to deny any intention to affect the curriculum or to appear to be assessing teaching - indeed it denied that it was anything to do with improving education, at one point, being just an instrument 'to produce and make generally available a national picture of some aspects of school performance' (DES, 1978). This is recognised as an untenable position, though it took some years of arguing and the publication of some survey results to achieve this change of heart. Certainly in the case of science, suspicion has died away as information has been made available as more people have been involved in consultation and results have been obtained which have relevance for teachers, not just administrators and politicians. The APU science surveys are now valued precisely because they do have curriculum implications, and dissemination and in-service activity have become a high priority. The tables have been turned: the profile is no longer low.

In a recent edition of 'Education News', Power (1983) discussed the pros and cons of national assessment in relation to the evaluation of the Australian Studies in Student Performance. The 'cons' were the following:

- that valued outcomes of education are complex, difficult to define and agree, and hence not susceptible to measurement;
- the validity of tests of essential skills and standards of performance applicable to all students is difficult, if not impossible, to establish;
- outcome measures alone tell nothing of the possible reasons for variations among groups of students;
- assessment programs can have negative backwash effect in the curriculum;
- national assessment programs are expensive: the funds would be better employed in other ways.

These are all very valid points; indeed I said very much the same about the APU during the period 1975-79 (Harlen, 1979). I am not claiming now that the APU science surveys have satisfactorily answered these points but rather, that despite this, the existence of the surveys has had a net positive influence. Some of the reasons are that, unlike ASSP, no attempt was made to identify cut-off points to indicate mastery. Levels of performance are published accompanied by a number of examples of questions so that the meaning can be judged by others. The emphasis upon measuring change has been played down (though this may reappear as a significant issue in the future) and emphasis laid upon differences among groups of pupils and, within all groups, upon differences in performance on different types of questions. Since a matrix sampling design is used, any one pupil in the survey takes only one of 20 to 30 different tests (the number varying with the age group) which are not parallel; the results of individual pupils and schools make no sense and are not calculated. Hence there is no possibility of schools' results being used for hidden purposes of evaluating teachers and schools. The wide range of test questions and the use of practical as well as written modes of testing mean that any curriculum backwash effect is likely to be in the direction of expanding the range of pupil activities rather than the reverse. Indeed a research project set up, in part, to evaluate the impact of the APU on schools concluded that the curriculum effect was a broadening one (Gipps, 1982). Finally the results have proved useful, mainly because they comprise not only the dry statistics, but detailed descriptions and categorisations of pupils' responses and errors. Also, information is obtained, as far as it can be by questionnaire, about the science curricula experienced by the pupils and the schools' resources for science teaching, and any associations between variations in these factors and variations in performance are explored and reported.

Thus, whilst it is still true that far from all the important outcomes of science education are covered and that the validity of the tests depends on the judgements of those who have devised and advised upon them, many of the other objections to national assessment have been met.

I doubt whether this would have happened, however, unless what is assessed was seen as worthwhile and relevant by teachers and so I would like to return to the early days of the APU's activity. In 1975 it had developed an assessment model 'based on lines of development across the curriculum rather than traditional subject area'. The six lines of development were described as mathematical, language, scientific, aesthetic, physical, and 'personal and social'. One reason for attempting to cut across subject boundaries was to avoid having a prescriptive influence on the curriculum; another, that it enabled the whole curriculum to be assessed without having a multitude of subject-specific assessments going on. The 'lines of development' model began to crumble as soon as working parties were set up to decide what should be assessed.

The first three working parties (mathematical, language and scientific) were made up of subject specialists who soon began to surround their work by the boundaries of traditional territories. Then foreign language and technology demanded a place in the APU - neither of these pretended to have meaning across the curriculum. Eventually decisions were taken to carry out monitoring in science, mathematics, and language only. Limited monitoring of a first foreign language is also in progress. A decision about technology is awaited, whilst decisions have been taken not to monitor in the other three lines of development of the initial model.

The working party on science had some difficulty in appreciating the point of the assessment but rather less in agreeing that, if anything was to be assessed, then the emphasis should be on scientific process skills. One fact explains both of these points - the members were five people who knew each other well and had all been involved in the development or dissemination of the Nuffield science projects of the late 1960s and early 1970s. We knew from experience that assesment of pupils alone would not be of much value, we knew there were other ways of finding information about the state of science teaching and we knew that the results of other large surveys (such as NAEP and the IEA) had negligible impact in respect of improving science education - a cause to which we were all dedicated. But we also knew that assessment is bound to have an effect on the curriculum, and that to take up the challenge of designing an assessment program which could assist the shift in emphasis from rote learning to process skills and concepts would be better than refusing to co-operate and risking someone else recommending a monitoring program based on multiple choice tests of factual knowledge.

The focus on process skills was agreed, partly because of the values and views of science of those involved, and partly for pragmatic reasons. With no national syllabus and a wide variety of programs and curriculum organisations it would have been impossible to define a body of content which could be said to be shared by all programs and agreed as worth assessing, whilst few teachers and other educators disagree that the process skills are important aims of science education. In fact, of course, we had to define both a list of process skills and a list of knowledge and concepts to be assessed, for there has to be some content when process skills are assessed.

At that point, however, I do not recall that the arguments for defining process skills and concepts paid much attention to their inter-relationship. We made, I believe, the right decision, but intuitively, without a coherent justification for the emphasis on process. Indeed I think we saw the need for a science content in which to assess the processes as a necessity for fact validity rather than a logical necessity for construct validity, which I at least now see it to be (APU, 1977).

The assessment framework, as currently defined, consists of the following categories and sub-categories of performance. It has evolved to this stage through applying a combination of theoretical analysis and empirical evidence. It is a working framework and an assessment framework. It makes distinctions between things which we have found we can assess separately and which it is useful to assess separately. Some of the changes which have been made are referred to in the subsequent discussion.

The assessment framework

<u>Category</u>	<u>Sub-categories</u>
1 Symbolic representation	Reading information from graphs, tables and charts Representing information as graphs, tables, charts Using scientific symbols and conventions
2 Use of apparatus and measuring instruments	Using measuring instruments Estimating physical quantities Following instructions for practical work
3 Observation	Making and interpreting observations Using a branching key
4 Interpretation and application	Interpreting presented information Distinguishing degrees of inference Applying science concepts to make sense of new information Generating alternative hypotheses
5 Design of investigations	Planning parts of investigations Planning entire investigations Identifying or proposing testable statements Using knowledge of experimental procedures
6 Performance of investigations	

PROCESS SKILL AND CONCEPT INTERACTION

There was a time when the development of processes and concepts in science were considered independently, sometimes even as alternatives to one another. Schemes, such as SAPA, were produced to emphasise processes and others, such as 'Concepts in Science', to emphasise concepts. People thought, and some still do, that processes can be taught using any content and be transferable to other content and that concepts can be taught without use of processes. But these aspects of behaviour

are not independent of each other in application or in learning. Studying children in classrooms, and more recently, in the test situations which we have been developing for the APU, has certainly advanced my ideas about the interdependence of skills and concepts and this experience of observing children forms the basis for the following thoughts.

Let me start with concepts - children's own ideas - there being no better starting point in this centre which has done so much to explore the nature and persistence of these ideas (Osborne *et al.*, 1979-82). Children's ideas, whether they are in line with those of scientists or are the everyday ones dubbed 'alternative frameworks', influence their use of process skills.

Take observation. Two children sat in front of two similar jars of water. The activity, a warm-up for Archimedes' principle, was to put a large stone into one jar and a small stone into the other. 'What do you notice?' asked the teacher. 'They made a plop and then there were bubbles in the water'. 'Anything else?' Silence. 'Did you notice any difference in the water levels?' prompted the teacher. 'No, the same happened in both but this stone made a bigger plop'. The teacher found that the children had not registered that the water level in one went up more than in the other. Their focus was on the stone, not the water. Left at that, the experience would have had very little of the illuminating effect it was supposed to have on the theory to be introduced.

Several other examples could be given where children don't seem to observe what is, to others, plainly observable. The 'spectacles' worn by teachers and pupils are often different and the spectacles are created by existing ideas. In the APU assessment framework there used to be two sub-categories of 'Observation': 'observing similarities and differences' and 'interpreting observations' (DES 1981, 1982a,b). In the first we set questions where pupils were expected to make and record observations only and in the second to do this and give an interpretation of them. The distinction turned out to be both rationally and statistically untenable, for it was clear that some interpretation was invariably involved in making observations and it was impossible to ask children to observe without some interpretation taking place which directed their attention.

Planning investigations is another process which is influenced by preconception. The variables that children consider should be controlled in a plan depend on their view of what might influence the result. Thus in an investigation about dropping balls onto different surfaces children thought that the person dropping the ball should be kept the same. This might be explained by everyday experience (that there are 'good' and 'bad' ball droppers) but it might also be part of the 'control everything in sight' syndrome which is possibly a child's defence to unthinking over-insistence by teachers.

on controls and fair testing. Creating hypotheses is also clearly influenced by existing ideas, for what can be thought up as a possible explanation depends on previous experience. Of all the connections that might be dreamed up children are more likely to settle on ones they have reason to believe might operate. The analogy with previous experience might be quite mistaken in the adult's view but it is whether it holds in the child's view that matters.

Thus concepts do more than influence the use of process skills; they are integral parts of the mental processes of taking in and making sense of evidence from the world around. I want to argue now that process skills are equally an essential part of science concepts formation and, indeed, hold the key to changing children's own (non-scientific) ideas into concepts which are of wide application and stand up to testing (i.e., scientific ones).

How do children form their non-scientific, alternative ideas? I don't think enough attention has been given to this question by the 'alternative frameworks' movement. Indeed we could well return to Piaget (surely the first to show that children have their own ideas) for the answer to this question in his discussions with children. In some of his later work Piaget asked children to predict the direction in which a ball should be fired across a smooth board in order to bounce off the edge at a given angle. When children drew the expected paths of the balls as not straight, they explained this in terms of their everyday knowledge of balls. Children's experience of balls is not on smooth boards but on bumpy paths or grass; they had seen balls change direction without apparently bouncing off anything and to them it was 'natural' for balls to move in erratic paths. Many of the ideas that children form must be gained this way, by jumping to (untested) conclusions that what has happened in one situation happens in others. Other ideas may be picked up from hearsay, based on others' superficial, unquestioned, experience. There are plenty of such ideas around. For example my mother 'taught' me that if the sun shone through the window onto the fire it would put the fire out, that maggots were made of cheese and developed spontaneously from it, that placing a loose fitting lid on a pan of boiling water made it boil at a low temperature, that electricity travelled more easily if the wires were straightened out. In my science education I found that these ideas did not stand up to the test of experience, but my mother still believes them. This is an important point for, as the 'Learning in Science Project' has shown, the everyday ideas which children have are ones which 'work' in everyday life, one can get by with them quite adequately. But if we want children to have ideas which have wider validity, that stand up to testing and form a basis for further scientific understanding, then we want children to use process skills in the development of their ideas.

My working with children confirms me in the belief that the ideas children use (rather than recite in class if asked to) are the ones based on their own thinking and experience. Learning is thinking. No-one else can do your thinking for you or present you with ready-made learning. What is important, therefore, is that children's school experiences allow them to think about, try out, and communicate ideas. This is the same, in my view, as saying that children should use process skills in learning. However, that is not all. For the skills themselves must be developed, otherwise their role in advancing ideas will not be realised.

It is not enough to let pupils observe things if their observation, as I suggested earlier, takes place within the field of view limited by their previous experience. The development of the skill of observation means going beyond this limitation. They can develop the skills of seeking new evidence consciously, of looking for patterns, of focusing on different parts of the phenomena and not just on what is to them the most obvious.

Only by raising the level of skill available to children will it be possible for them to test out existing ideas, change or reject them. This will involve development and application of all the science process skills. When interpreting data pupils have to be taught how to go beyond picking out just those parts of the data which fit their preconceptions and to find alternative, more powerful generalisations which fit all the data. Some of these will come from the teacher, particularly some of the more abstract ideas. Whatever their origin these generalisations have to be considered tentatively and tested out. If pupils take part in planning such tests they will understand far more about the ideas being considered than if they simply follow instructions or watch someone else carrying them out. But in order to do so they need the skills of planning; they need the ability to consider a problem in a general form and be able to identify the factors to be varied and controlled and the observations or measurements to make. They need also to be able to translate this general planning into operational terms, preserving the link between the operational details and the general plan. Too often pupils can work through a so-called experiment, planned by someone else, without any idea as to why they are doing things or why the teacher is doing them. For example the whole point of the constant volume gas thermometer is lost on many children when the operational details of 'getting the mercury to the mark' are stressed and what this means in terms of gas volume is not understood.

Through using process skills in testing ideas pupils will gain a healthy scepticism about the basis of ideas and about generalising from evidence. They will gain some insight into how knowledge is generated by experiencing this process to some extent. Though most of the ideas they encounter in science will have been generated by

others, they will certainly not be prepared to accept ideas which are either incapable of being tested or are in conflict with evidence.

What I am attempting to describe is a learning context in which ideas become children's own only after they are satisfied that the ideas stand up to their tests and fit their present experience. It is, I hope, clear that this is more than showing children evidence dissonant with their non-scientific ideas. We have been trying this in secondary science lessons for a long time and the 'Learning in Science Project' would have been out of business had it worked. What I hope I have expressed is the case for process skill development as an essential to concept development. The use of mental processes can lead the formation and transformation of ideas but to do this the mental skills have to be consciously developed.

BACK TO THE APU

The process/concept discussion may seem to have taken us a long way from the APU. In my thinking this is not the case; it is just part of the thinking about what it is that is important enough to spend so much money, time, and effort assessing. Were there not such a close and causal relationship between processes and concept it would be difficult to justify the process focus of the assessment framework. For whilst it is true that most teachers pay lip-service to the value of process skills, as aims in their own right, it is equally true that, as a member of the APU's Consultative Committee wrote recently in commenting on the report of science at the age of 15 (APU 1982b): 'What is being measured may not match exactly what is current practice in our schools' (APU 1983). What is current practice was described by HMI (DES 1979) as over-directed teaching, too much time spent on the dictated note, too little time on experimental work and teaching methods strangled by the demands of external examinations.

Had the APU science framework reflected this current practice the emphasis would have been upon knowledge of principles and facts. The results would have shown the general degree of ability to recall these things, but would undoubtedly have met the reaction 'so what?'. The emphasis upon process skills, given the arguments about their centrality in concept formation, means that the results have diagnostic value. We have found, particularly at the lower two ages, 11 and 13, evidence that skill development is at the superficial level consistent with the everyday, non-scientific concepts. Further, in those questions where application of concepts is tested, performance is influenced more by the type of question than by the concept demand. There are indications, therefore, that weaknesses in process skills are limiting pupils' ability to understand and explain the phenomena in their world.

I would not pretend that this type of finding is any more easy to interpret and to use than a percentage score from multiple choice questions about, for instance, magnetism. We still have to face the questions about how the observed performance relates to the children's experience and how improvement might be brought about where it is considered desirable. For this much more needs to be known about the teaching in school and about what is known to be a very strong influence on children's performance, their home background. Some of the relevant work has been done by other research projects. More research is planned and indeed a significant part of the APU work in science for the five years following 1984 will take the form of research aimed at understanding more about how the observed variations in performance originate. In the meantime the discussion of the assessment framework and of results so far obtained have caused science teachers to look at their own values and practices and to reconsider the relative emphasis in their own work on process skills and concepts.

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Footnotes: These should not be used although Reference Notes, e.g., Smith (Note 1) may be used to refer to unpublished material. The reference notes are to be collated at the end of the paper, e.g.,

Note 1, J.J. Smith, personal communication

Note 2, K.E. Jones, 'Myths about science teaching', paper presented at the Regional Directors' Conference, Darwin, May, 1980.

References: References to journals and books should follow the criteria of the A.P.A., (see American Educational Research Journal, Vol.18, No.1, for a summary).

In the general text of the paper references should appear as Bernstein (1971) or Fisher and Fraser (1983), then these references should be placed in the reference list as,

BERNSTEIN, B. Class, codes and control. London, Routledge & Kegan Paul, 1971.

FISHER, D.L., & FRASER, B.J. A comparison of actual and preferred classroom environments as perceived by science teachers and students. Journal of Research in Science Teaching, 1983, 20, 55-61.

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